992776

TECHNICAL MANUAL

TMA 3000
TAPE MOTION ANALYZER
48-420 Hz/115-230 VAC

MILITARY NOMENCLATURE
ANALYZER, TAPE MOTION
TS-4070/USH-24(V)

INSTALLATION AND OPERATING INSTRUCTIONS

MP MASTER
MA23461

DATATAPE DIVISION
300 Sierra Madre Villa, Pasadena, California 91109

BELL & HOWELL

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1-13. REFERENCE DATA.

(Table 1-1)

1-14. Equipment specifications and performance characteristics are listed in table 1-1.

ITEM	CHARACTERISTIC
ELECTRICAL CHARACTERISTICS	
Power Requirements	115 V ac ±10 percent, 48-420 Hz, single phase (or 230 V ac).
Electrical Protection	1 amp slow-blow fuse on high side of input line for 115 V ac operation (0.5 amp slow-blow for 230 V ac configuration).
PERFORMANCE SPECIFICATIONS	
Reference Frequencies	1.56, 3.13, 6.25, 12.5, 25, 50, 100, 200, 400 kHz, ±0.01 percent.
Low Pass Filter Bandwidths (Flutter Mode)	0.156, 0.313, 0.625, 1.25, 2.5, 5, 10, and 20 kHz (at ±5 percent).
Low Pass Filter Bandwidths (Time Base Mode)	0.156, 0.313, 0.625, 1.25, 2.5, and 5 kHz (at ±5 percent); 10 and 20 kHz (at ±7.5 percent).
Frequency Meter	10 Hz resolution; ±0.01 percent accuracy.
Flutter Measurements	IRIG standard 9 tape speeds: 15/16 to 240 ips.
Demodulated Output	1.0 volt pp (±5 percent) for a full-scale output.
Flutter Ranges, Full Scale	0.01, 0.03, 0.1, 0.3, 1, 3, 10 percent pp.
Time Base Error Ranges, Full Scale	0.3, 1, 3, 10, 30, 100, 300 microsec pp.
Measurement PP Meter	0 to 1 and 0 to 3.16 scales.
Instrument Accuracy	±5 percent of full scale.

Table 1-1. Specifications and Performance Characteristics (Sheet 1 of 3)

ITEM	CHARACTERISTIC
Sigma Levels	1σ (exclude peaks occurring < 32 percent of time). 2σ (exclude peaks occurring < 5 percent of time). 3σ (exclude peaks occurring < 0.3 percent of time).
Operating Environment	0° to 55°C. 5 to 95 percent relative humidity (non-condensing).
INPUT POWER REQUIREMENTS	
Power Input	50 VA maximum.
INPUTS - Front Panel	
FLUTTER TBE/SKEW	Flutter input, used in TBE/SKEW.
SERVO TBE/SKEW	Servo input, used in TBE/SKEW.
Sensitivity	50mV rms to > 10V rms. Inadequate signal level results in flashing LED in meter range.
INPUTS - Rear Panel	
FLUTTER TBE/SKEW SERVO TBE/SKEW	Identical inputs on rear panel are selectable by front panel switch, from interface, or automatically in TRACK mode.
OUTPUTS - Front Panel	
REF OUT	Square wave at selected reference frequency; level is nominally 3V pp into 50 ohms from 50-ohm source. Internal adjustment permits setting reference level over approximately 0.5V pp to 5V pp into 50 ohms.
DEMOD OUT	Analog output for monitoring signal being measured by statistical voltmeter. Calibrated output level is 1V pp for full scale meter deflection. Source impedance 600 ohms.

Table 1-1. Specifications and Performance Characteristics (Sheet 2 of 3)

ITEM	CHARACTERISTIC
OUTPUTS - Rear Panel	
BPF OUTPUTS FLUTTER TBE/SKEW SERVO TBE/SKEW	Two analog outputs. Each output is the respective input after leveling (~3V pp) and filtering in the input channel conditioner. Input filter characteristics are approximately -10, +20 percent around nominal reference frequency.
PHYSICAL CHARACTERISTICS	
Height	3.75 inches.
Width	17 inches.
Depth	13.25 inches.
Weight	14 pounds 5 ounces.

Table 1-1. Specifications and Performance Characteristics (Sheet 3 of 3)

1-15. OPTIONS AND ACCESSORIES.

1-16. The following options and accessories are available for the TMA 3000:

a. Carrying Case, PN 552117.

b. Rack Mount Adapter, PN 552116.

c. IEEE 488 Interface, PN 552114.

d. RS-232C Interface, PN 552115.

1-17. ABBREVIATIONS.

1-18. The abbreviations used in this manual are as follows:

ABBR	MEANING
A/D	Analog to digital
AFC	Automatic frequency control
AGC	Automatic gain control
ANA	Analyzer
ATE	Automatic Test Equipment
BPF	Band pass filter
BW	Bandwidth
CAL	Calibrator/Calibration
CMOS	Complementary metal oxide semiconductor
Cont	Continued
DCE	Digital-to-analog converter
DAC	Data Communications Equipment
D-MOD	Demodulator
DTE	Data Terminal Equipment
EMI	Electromagnetic interference
FM	Frequency modulation
Freq	Frequency
IC	Integrated circuit
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/output
IPS	Inches per second
IRIG	Inter-Range Instrumentation Group
LED	Light emitting diode
LPF	Low pass filter
PP	Peak-to-peak
RAM	Random access memory
Ref	Reference
Rem	Remote
Rep	Reproduce
ROM	Read only memory
SNR	Signal-to-noise ratio
TBE	Time base error
TMA	Tape Motion Analyzer
VOM	Volt ohm milliammeter
VOM	Volt ohm milliammeter
σ	Sigma

3-24. TIME BASE ERROR (TBE) USING SERVO MODE. (Figure 3-6.)

3-25. Some tape recorders (such as the Bell & Howell VR3700 series and System J) generate a duty-cycle modulated square wave whose leading edge is derived from the reference oscillator and whose trailing edge comes from the reproduce control track or the capstan optical encoder. The SERVO mode affords a quick method to check system performance by looking at the servo error signal. This operation does not conform to the IRIG requirements, however, and is subject to errors if risetimes are not very fast and duty cycles depart significantly from 50 percent. The SERVO mode is recommended primarily for comparative purposes.

3-26. DYNAMIC SKEW MODE. (Figure 3-7.)

3-27. Skew measurements are performed in an identical manner to TBE (actually TBE may be considered a special case of skew) except that neither channel is a "reference." The measurement is a true differential between channels.

3-28. Skew perturbations tend to occur at low rates; for example, a major source of skew is the wobble in tape reels. The wobble rate may be as low as 1/50 times the tape speed in inches. The TMA 3000 measurement channel lower cutoff frequency (high pass) is slightly less than 0.5 Hz, and may produce lower skew readings (particularly at speeds less than 30 ips) than would result from the traditional oscilloscope methods.

3-29. CALIBRATION MODE. (Figure 3-2.)

3-30. In the calibration mode, a signal generated internally from the crystal controlled reference oscillator is applied to the channel input(s). If CAL (calibration) is entered from the FLUTTER mode, the calibration signal is 25 kHz modulated exactly 10 percent pp by a square wave at 195 Hz. If CAL is entered from TBE/SKEW mode, the calibration signal is two 25 kHz square waves whose time displacement is modulated exactly 10 usec pp at the same 195 Hz rate. By applying the signals at the input channels, virtually all of the TMA 3000 flutter and TBE channels are checked (input, demodulator, statistical voltmeter, frequency meter, analog meter, and by implication, the microprocessor). In the CALibrate mode, 1σ is automatically selected to minimize the effects of square wave overshoot in the low pass filters. In the FLUTTER CAL mode, the effective frequency applied is slightly above 25.000 KHz, and a meter reading of 25.04 to 25.09 may be observed. In the TBE/SKEW CAL mode, the observed frequency will be exactly 25.00 KHz.

3-31. The calibration signals are generated digitally from the 8 MHz crystal clock, with all signal timing directly (and synchronously) derived from the crystal. Calibration signal accuracy is inherently $\pm$0.01 percent with no adjustment required or possible.

3-32. The CALibrate mode is actually a calibration check, with no adjustments performed automatically. Rather, it serves as a confidence check to demonstrate accurate operation or to disclose measurement errors. A reading which differs from full scale by more than $\pm$3 percent indicates possible problems; an error greater than $\pm$5 percent is out of calibration and implies that service is required.

3-33. ANALYZER.

3-34. The built-in wave analyzer may be used to observe individual frequency components of the flutter or TBE/SKEW measurement in progress. Logically, the analyzer is imposed between the low pass filter and statistical voltmeter. When ANA (analyzer) is selected, the frequency meter reads the center frequency of the analyzer band pass filter.

3-35. The analyzer may be tuned over the range of 0.2 Hz to 20 kHz in five decade ranges. Ranges are incremented and decremented by the ANA RANGE switches. Analyzer bandwidth is $\pm$5 percent of the center frequency (-3 dB). With ANA selected, the analyzer output signal is routed to the DEMOD OUT connector on the front panel for monitoring.

3-36. When the analyzer is in use, the TMA 3000 sets the low pass filter (LPF) bandwidth to the minimum that will pass all components in the selected analyzer range, subject to the limitation that the LPF bandwidths cannot exceed 1/5 of the carrier frequency. An attempt to use the analyzer at center frequencies greater than the LPF bandwidth will obtain erroneous measurements.

3-37. REMOTE MODE.

3-38. If the TMA 3000 is equipped with an IEEE 488 or an RS-232C interface, it may be controlled from a remote computer or terminal. With the interface installed, the unit is always responsive to incoming commands. A supplemental Remote (REM) mode may be activated either by pressing the REM button on the front panel or by sending the REM/ON command from the computer. In the remote mode, the TMA 3000 will not respond to the front panel pushbuttons (other than REM), thus minimizing the possibility of accidentally interrupting an important measurement. The operator may override the remote status, however, by pressing the REM button or by sending a REM/OFF command from the computer. Taking the unit out of REM mode does not inhibit commands from the computer, but does enable the operator to issue commands.

3-39. All control commands are in the form of ASCII strings with mnemonics corresponding closely to the front panel labels. The external computer is able to specify reference frequency, filter bandwidth, mode, meter range, and analyzer center frequency directly rather than by UP/DOWN commands. In all other respects, remote operation is identical to manual operation.

3-40. OPERATION PROCEDURES FOR MEASUREMENT MODES.

3-41. Perform the following procedures to conduct the measurement modes.

a. Preliminary.

1. Place the TMA 3000 in operational readiness.

2. Place the recorder to be checked in normal operational readiness condition.

b. Procedure.

1. If desired, run TMA 3000 calibration check by pressing CAL (MODE) switch (figure 3-2).

2. Make interconnections between TMA 3000 and recorder in accordance with diagram in figure for specific measurement to be conducted (figures 3-3 through 3-7).

3. Set up TMA 3000 controls as listed in figure for selected measurement (figures 3-3 through 3-7).

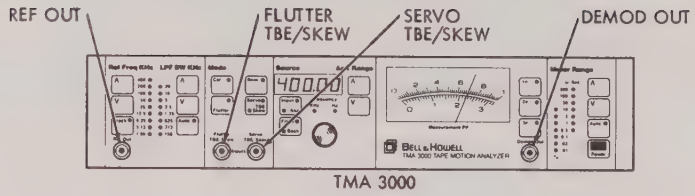
4. Conduct selected measurement, reading meter in accordance with selected meter range and compare readings to manufacturer specifications for recorder.

NOTE

System transients or discontinuities in the reference frequency signal may cause the analog meter to go off scale temporarily; pressing the lighted SIGMA switch will perform a brief reset of the measurement channel and clear this condition.

5. Conduct other desired measurements by repeating above steps 2 through 4.

6. Disconnect interconnections and return units to normal operational readiness.



Calibration mode requires no external connections, nor is it necessary to remove any existing connections.

MODE - FLUTTER, or TBE/SKEW

NOTE

In CAL, a full scale meter indication should be observed with a frequency reading of 25.04 to 25.09 kHz (FLUTTER) or 25.00 kHz (TBE/SKEW).

Other settings at any selection - The TMA 3000 automatically selects the correct conditions for calibration. When the calibration mode is exited, the previous settings are restored.

Figure 3-2. Operation in Calibration Mode

SECTION V

MAINTENANCE INSTRUCTIONS

5-1. SCOPE OF SECTION.

5-2. This section contains information and instructions for maintaining the TMA 3000 Tape Motion Analyzer. Included are instructions for adjustment and calibration, troubleshooting, and repair. No special tools or equipment are required to perform these procedures.

5-3. REFERENCE DESIGNATORS.

5-4. For ease of identifying circuit boards of the TMA 3000 in this section, the following arbitrary alphanumeric designators are assigned:

Board Assy	Designator	B&H Part No.
3024 Interconnect	A1	552100-6000
3020 Input Channel 1	A2	552100-9000
3020 Input Channel 2	A3	552100-9000
3004 Microprocessor	A4	552100-7000
3041 D-MOD	A5	552100-8000
3008 IEEE 488	A6	552108
3012 RS-232C	A7	552109
3037 Power Supply	A8	552100-4100
3016 Display	A9	552100-2100

5-5. INSTRUMENTATION TECHNIQUE.

5-6. The following basic requirements for maintenance measurements should be adhered to in the calibration of the TMA 3000.

a. Monitor test points with calibrated low capacitance oscilloscope probes. Always use probe ground clips with short (6 inches or less) leads.

b. Monitor frequencies by connecting counter to oscilloscope outputs, using low capacitance probe as required.

c. Proper termination of signal sources is essential to waveform purity and measurement accuracy.

d. Allow 20 minutes for the TMA 3000 and all calibration equipment to warm up.

5-7. ADJUSTMENT AND CALIBRATION.

5-8. INSTRUMENT ACCESS. Performance verification, metering, and adjustment of the TMA 3000 require electrical access to test points and connectors, and physical access to adjustments. Such access is provided by performing the following steps with the ac power disconnected.

a. Procedure.

1. Remove four Phillips-head screws securing top cover. (Do not loosen or remove nickel-plated, oval-head screws that secure front-panel hold-down rail.) Hinge-mounted microprocessor board (A4) is exposed.

2. Remove two 8-32 screws that secure aluminum tray of microprocessor A4 board.

3. Lift front edge of microprocessor A4 board, which hinges from back, until A4 board is tilted back far enough for attached phenolic support leg to rest on top of power transformer to support weight of A4 board. (Ensure that phenolic leg goes into prop position to avoid physical contact with components and possible damage.)

5-9. MAINTENANCE CHECKS AND ADJUSTMENTS. Table 5-1 is a maintenance reference, which is a list of maintenance adjustments with cross references to the paragraph for the respective adjustment procedure. Locations of test points and adjustments are illustrated in figure 5-1. It is recommended that the following checks and adjustments be performed in the sequence presented.

5-10. Initial Performance Check. A rapid performance check may be made by performing the following abbreviated test procedure. The results of these tests do not certify calibration, but are an indication of whether the circuits are functional or in need of repair.

a. Procedure.

1. Plug power cord of the TMA 3000 into power receptacle and press POWER switch to on. Observe that one or more panel indicators light.

2. Press MODE pushbuttons FLUTTER and CAL to selected mode.

NOTE

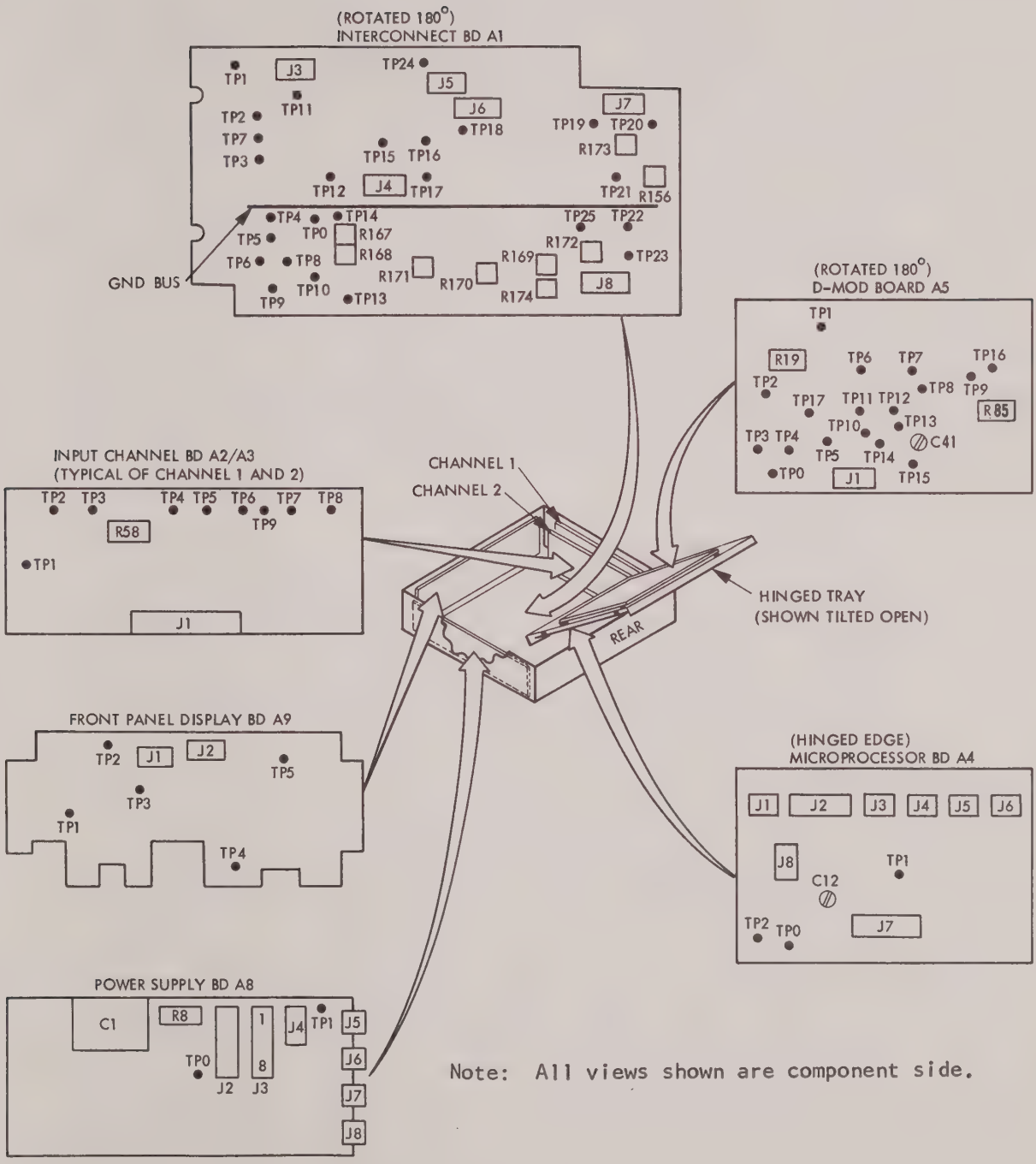
Placing TMA 3000 in CAL mode internally connects precision calibration signal to input of flutter channel, which allows operator to verify operation through principal flutter-measuring path. In CAL mode, TMA 3000 selects 25 kHz REF FREQ, 2.5 KHz LPF BW, 1 sigma, and 10% meter range.

3. Verify that measurement pp meter reads exactly 10%.

4. Verify that digital FREQUENCY meter displays readout of approximately 25.080 KHZ $\pm$4 Hz.

NOTE

If readings of steps 3 and 4 are as specified, then majority of TMA 3000 functions are operational.



Note: All views shown are component side.

Figure 5-1. Adjustments and Test Point Locations, TMA 3000

PARA NO.	ADJUSTMENT	REF DES OF ADJUSTMENT	ADJUSTMENT SPECIFICATION
5-11	Adjust regulated +5 volt power supply	A8 R8	5.000 ±0.005 Vdc at A8 J3-1
5-12	Adjust microprocessor or clock frequency	A4 C12	8,000,000 Hz ±80 Hz at A4 TP2
5-13	Adjust reference frequency output level	A1 R156	3 Vpp ±5% at REF OUT connector
5-15	Adjust meter zero (deenergized)	Zero adj at back of meter	Calibration zero as viewed from face
5-17	Adjust meter gain	A1 R172	Adjust for full scale as read
5-19	Adjust voltage reference	A1 R173	2.500 Vdc readout at A1 TP20
5-20	Adjust TBE/Skew gain (time scale)	A5 R85	Full scale (10 us) read on meter face
5-21	Adjust flutter gain (percent)	A5 R19	Exactly 10% read on meter
5-23	Adjust analyzer limits	A1 R174	1.95 KHz on frequency meter
		A1 R170	20.5 KHz on frequency meter
5-24	Adjust analyzer	A1 R171	Peak meter reading
		A1 R168	10% meter reading
		A1 R169	205.0 Hz readout on frequency meter
5-25	Adjust input range sensitivity	A2 R58	For flashing 10% range LED
		A3 R58	For flashing 3 usec range LED

Table 5-1. List of Maintenance Adjustments

5. Press CAL pushbutton to deselect calibration mode.

6. Press FLUTTER pushbutton to deselect flutter mode.

7. Press MODE pushbuttons TBE/SKEW and CAL to selected mode (TMA 3000 is again reading on internal calibration signal).

8. Verify that digital FREQUENCY meter displays readout of 25.00 KHz.

9. Verify that measurement pp meter reads 10 microseconds.

10. If readings of steps 9 and 10 are as specified, then both input channels and TBE demodulator are functional.

11. Deselect CAL and TBE/SKEW MODE pushbuttons to complete check.

5-11. Check Power Supply Voltages. Before proceeding with calibration, power supply voltages should be verified to eliminate possible repetition of steps caused by misadjusted or faulty power supplies. Power supply voltages are verified by performing the following steps.

a. Preliminary.

1. Perform procedures of paragraph 5-8 (power off) to gain access to test points and adjustments. (See figure 5-1 for locations of all test points and adjustments.)

2. Connect common lead of digital voltmeter (dc range) to horizontal ground bar running across middle of interconnect A1 board. Visually locate connector A3 J3 on power supply A8 board.

b. Procedure.

1. Press POWER pushbutton to on. Observe that panel indicator lights.

2. Connect digital voltmeter input to pin 1 (at top) of power supply connector A8 J3 and verify that voltmeter readout displays +5.000 ±0.005 volts dc.

3. If +5 volt supply is out of tolerance, use adjustment screwdriver and adjust potentiometer A8 R8 on power supply board until voltmeter readout displays +5.000 ±0.005 volts dc. Disconnect voltmeter.

4. Connect digital voltmeter input to pin 3 of connector A8 J3 and verify that voltmeter readout displays +6.00 ±0.30 volts dc. Disconnect voltmeter.

5. Connect digital voltmeter input to pin 5 (reverse polarity) of connector A8 J3 and verify that voltmeter readout displays -6.00 ±0.30 volts dc. Disconnect voltmeter.

6. Connect digital voltmeter input to pin 6 of connector A8 J3 and verify that voltmeter readout displays -12.00 ±0.60 volts dc. Disconnect voltmeter.

7. Connect digital voltmeter input to pin 8 (bottom) of connector A8 J3 and verify that voltmeter readout displays +12.00 ±0.60 volts dc. Disconnect voltmeter.

8. If any power supply output measurement fails to meet any requirement of the previous steps, refer to troubleshooting procedures; if power supply voltages are as specified, continue with next adjustment procedure.

5-12. Microprocessor Clock Adjustment.

a. Procedure.

1. Connect frequency counter to test point A4 TP2 on microprocessor A4 board, using test point A4 TP1 as signal ground.

2. Verify that frequency counter measures 8,000,000 Hz ±80 Hz.

3. If measured frequency is not within specified tolerance, use non-metallic tool and adjust variable capacitor A4 C12 until frequency is within specified tolerance.

4. Disconnect frequency counter.

5-13. Reference Frequency Generator Level Adjustment.

a. Procedure.

1. Connect test oscilloscope to front panel bnc connector marked REF OUT, using coaxial cable terminated with 50 ohms.

2. Verify that oscilloscope displays 3.00 ±0.15 volts pp wave form.

3. If amplitude of displayed wave form is not as specified, use adjusting screwdriver and adjust potentiometer A1 R156 for display of 3.0 ±0.1 volts pp.

NOTE

Depending on user application, an output level different than specified may be desired. Adjustment to a different level does not affect any other calibration step.

4. Use a frequency counter connected to the oscilloscope buffered output with the same oscilloscope setup as described above, and step through all nine operating frequencies (press up or down buttons as required).

5. Verify that outputs exist for each selected frequency and that all are of equal amplitude. (Some rolloff or rounding of output wave form at 200 KHz and 400 KHz is typical.)

6. Disconnect test setup.

5-14. Gain Amplifier Check. Check tracking of the Gain Amplifier by performing the following steps.

a. Procedure.

1. Unplug ribbon cable running from D-MOD A5 board at connector A1 J6 of interconnect board.

2. Select operating conditions at front-panel pushbuttons as follows:

Control	Setting
REF FREQ	200 KHz
LPF BW	10 KHz
MODE	FLUTTER
SIGMA	2σ
RANGE	10%

3. Connect ac voltmeter (HP 400E or equivalent) to DEMOD output bnc connector on front panel.

4. Connect 1 kHz sine-wave source, that has an accurate attenuator, (HP 651B or equivalent) to test point A1 TP18 (use test point A1 TP15 for ground).

5. Set sine-wave source frequency to 1 kHz and set output level for full-scale indication on measurement pp meter (full scale occurs at about 360 millivolts rms input).

6. Verify that DEMOD output level is approximately equal to level of sine-wave source output level.

7. Reduce sine-wave source input by 10 dB using HP 651B attenuator and decrement METER RANGE from 10% to 3% by pressing meter down-arrow push-button.

8. Verify that measurement pp meter again reads full scale and that DEMOD output level returns to level read in step 6.

9. Continue reducing input level and down ranging measurement pp meter (pressing down-arrow pushbutton) in 10 dB steps, verifying that measure-ment pp meter reads full scale and DEMOD output level returns to level read in step 6 for each 10 dB reduction in signal level.

NOTE

Failure to meet criteria of any of above steps is cause for troubleshooting TMA 3000.

Accurate tracking of gain amplifier indicates that TMA 3000 calibration will track from range-to-range.

10. Remove power to TMA 3000, disconnect test setup, and reconnect ribbon cable (removed in step 1) to connector A1 J6 on interconnect board.

5-15. Meter Zero Adjustment.

a. Procedure.

1. With TMA 3000 power turned off, visually examine the measurement pp meter from a 90-degree angle with the meter face at the zero mark (i.e., view straight in to avoid parallax errors). Verify that meter indicator is pointing exactly to the zero graduation mark (lightly finger-tap the meter case to ensure that there is no pointer offset due to friction).

2. If the indicator is not pointing exactly to the zero mark, use adjusting screwdriver to adjust pointer to exactly zero (this adjustment is accessible from the back of the meter case).

5-16. Low-Pass Filter Check. DO NOT SWITCH ON POWER !!

a. Preliminary.

1. Connect a coaxial cable, with bnc connectors at both ends, between TMA 3000 front panel connectors marked REF OUT and FLUTTER TBE/SKEW.

2. Remove shield from D-MOD A5 board (on underside of microprocessor board tray) to gain access to D-MOD board test points.

3. Press POWER button to on.

4. Set front-panel controls for operation as follows:

Control	Setting
REF FREQ	200 KHz
LPF BW	20 KHz
MODE	FLUTTER
SIGMA	2σ
RANGE	10%

a. Procedure.

1. Use Model HP 651B oscillator as signal source set to 1 kHz, and connect output to test point A5 TP2 of D-MOD board (use test point A5 TP0 for signal ground) to apply test signal to flutter demodulator.

2. Adjust oscillator 1 kHz output for full-scale indication on measurement pp meter. (Note that approximately 2.0 volts rms at A5 TP2 produces a full-scale indication on measurement pp meter.)

3. While maintaining constant oscillator output level, increase oscillator frequency until measurement pp meter indicates 0.707 (i.e., -3dB level). Verify that -3dB frequency is 20 ±1 kHz. (Always approach band edge from lesser frequency.)

4. Repeat step 3 for remaining filter bandwidth ranges (step LPF BW down with down-arrow button to each range) and verify for each range setting that -3dB frequency is within tolerance specified below:

LPF Bandwidth (Fluttter Mode)

10 KHz (±500 Hz)
5.0 KHz (±250 Hz)
2.5 KHz (±125 Hz)
1.25 KHz (±62.5 Hz)
0.625 KHz (±31.3 Hz)
0.313 KHz (±16 Hz)
0.156 KHz (±8 Hz)

5. Press SERVO TBE/SKEW button to place TMA 3000 in SERVO mode, remove coaxial cable from FLUTTER connector and connect to SERVO TBE/SKEW connector.

6. Move HP 651B oscillator output to test point A5 TP9 (disconnected from A5 TP2) of D-MOD board (use test point A5 TP16 for signal ground).

7. Select LPF BW of 20 kHz, set HP 651B oscillator to 1 kHz and adjust output signal level for full-scale indication on measurement pp meter. Use this 1 kHz output as a 0dB reference for all bandwidth checks to follow and maintain oscillator output at this level for all frequencies without regard for subsequent measurement pp meter readings.

8. Increase oscillator frequency (maintain level of step 7) until measurement pp meter drops to 0.707 (-3dB). Verify that -3dB frequency is 20 ±1.5 KHz. (In steps to follow, always approach band edge from lesser frequency.)

9. Repeat step 8 for remaining filter bandwidth ranges (step LPF BW down with down-arrow button to each range) and verify for each range setting that -3dB frequency is within tolerance specified below:

LPF Bandwidth (Time Base Mode)

10 KHz (±750 Hz)
5.0 KHz (±250 Hz)
2.5 KHz (±125 Hz)
1.25 KHz (±62.5 Hz)
0.625 KHz (±31.3 Hz)
0.313 KHz (±16 Hz)
0.156 KHz (±8 Hz)

NOTE

This completes filter bandwidth tests; failure to meet specifications of any of prior steps is cause to conduct TMA 3000 troubleshooting before continuing. Successful completion of these steps verifies that TMA 3000 data paths are functional and acceptable for procedures that follow. (When filters are checked in the manner described, SERVO bandwidths are typically slightly greater than FLUTTER bandwidths, but are acceptable if specifications are otherwise met.) Do not disconnect test setup.

RETURN LPF BW TO 20KHz.

5-17. Meter Gain Adjustment.

a. Procedure.

1. Leave HP 651B connected to D-MOD board test point A5 TP9 as used in prior checks. Connect digital voltmeter (4-1/2 digits or more on readout) to interconnect board test point A1 TP22 (use mid-board ground bar for signal common).

2. Set oscillator (1 kHz) output level until digital voltmeter (at A1 TP22) reads 4.000 volts dc.

3. Verify that measurement pp meter reads at full-scale deflection. If this meter does not read exactly full scale, use adjusting screwdriver and adjust interconnect board potentiometer A1 R172 for exactly full-scale deflection.

4. Disconnect test setup.

5-18. Sigma Check.

a. Procedure.

1. Connect function generator (Wavetek 143 or equivalent) output to test point A5 TP2 of D-MOD board (use test point A5 TP0 for signal ground).

2. Set LPF BW to 20 KHz range.

3. Adjust function generator to frequency of 300 Hz and select triangular waveform output function.

4. Connect coaxial cable between TMA 3000 bnc connectors REF OUT and FLUTTER TBE/SKEW. IF 10 7754 MODE

5. Select 2 sigma (2σ) on TMA 3000 and adjust function generator, triangular-wave, output level to produce a .95 indication on measurement pp meter.

6. Select 3 sigma (3σ) and verify that measurement pp meter indicates 1.00 $\pm$0.02.

7. Select 1 sigma (1σ) and verify that measurement pp meter indicates 0.68 $\pm$0.02.

NOTE

Failure to meet specification of steps 6 and 7, indicates a malfunction requiring troubleshooting of the statistical voltmeter circuit.

8. Disconnect test setup.

5-19. Voltage Reference Adjustment.

a. Procedure.

1. Connect digital voltmeter to interconnect board test point A1 TP20 (use ground bus for voltage ground).

2. Verify that digital voltmeter reads out exactly 2.500 volts dc.

3. If measured voltage is not as specified, adjust interconnect potentiometer A1 R173 until reference voltage is within specification.

4. Disconnect test setup.

5-20. TBE/SKEW Gain Adjustment. Because there is no accurate source of TBE/SKEW test signals, the TMA 3000 contains a built-in test signal generator. This internal calibrator derives its signals digitally from a crystal-controlled, reference-frequency oscillator within the TMA 3000. Provided the oscillator and the digital logic are both operational, the calibration generator is accurate to $\pm$0.01 percent or better.

a. Procedure.

1. Place TMA 3000 in TBE/SKEW mode.

NOTE

Choices of REF FREQ and LPF BW switch selections are not important for these tests and may be ignored.

2. Select CAL MODE. (This causes TMA 3000 to automatically select 25 KHz REF FREQ, 2.5 KHZ LPF BW, 1 Sigma, and 10-Microsecond Meter Range.)

3. Verify that measurement pp meter indicates full scale (10 microseconds). If meter does not read full scale, adjust potentiometer A5 R85 on D-MOD board for full-scale indication.

NOTE

Variable capacitor A5 C41 is not adjusted in this procedure. This capacitor is normally adjusted in the 1.0 microsecond range and requires a special test signal generator. Should the 1.0 microsecond TBE/SKEW range appear to be out of calibration, or if any component in the TBE measuring circuits require replacement, contact the nearest Bell & Howell field office.

5-21. FLUTTER Gain Adjustment. To effect flutter gain adjustment, perform the following steps.

a. Procedure.

1. Select FLUTTER and CAL modes. (The TMA 3000 automatically goes to 25 KHz REF FREQ, 2.5 KHz LPF BW, 1 Sigma, and 10% analog Meter Range. Calibration signal derived digitally from the TMA 3000 crystal-controlled reference oscillator is introduced into FLUTTER measurement channel.)

2. Verify that measurement pp meter indicates exactly 10% (full scale). If meter does not indicate exactly 10%, then adjust potentiometer A5 R19 on D-MOD board until meter reads exactly 10% (i.e., full scale).

NOTE

The cablibration procedures described in paragraphs 5-14 through 5-17 ensure correct calibration on ranges and filter bandwidths other than those covered in this paragraph. If further calibration points are desired, an appropriate test signal may be generated by frequency modulating a function generator. Most function generators are sufficient as flutter simulators down to approximately 0.1 percent modulation.

5-22. FREQUENCY Meter Check.

a. Procedure.

1. Using a bnc T-connector and a short length of coaxial cable, connect the reference frequency REF OUT to the FLUTTER TBE/SKEW input. Also, connect an external frequency counter to the REF OUT connector to monitor output accuracy.

2. Verify that FREQUENCY meter digital readout displays correct frequency for each of nine frequency selections (i.e., 1.56 KHz to 400 KHz). Failure to produce readout of selected frequencies is a malfunction, requiring troubleshooting.

3. Disconnect coaxial jumper cable.

5-23. Analyzer Limits Adjustment.

a. Procedure.

1. Select ANA function and use ANA RANGE up button to select 20 KHz analyzer range (digital readout).

2. Turn front-panel potentiometer fully counterclockwise and verify that FREQUENCY digital meter readout displays 1.95 KHz. If readout is not as specified, adjust interconnect board potentiometer A1 R170 for readout of 1.95 KHz.

3. Turn front-panel potentiometer fully clockwise and verify that FREQUENCY digital meter readout displays 20.5 KHz. If readout is not as specified, adjust interconnect board potentiometer A1 R174 for readout of 20.5 KHz.

4. Because of interaction between adjustments of potentiometers A1 R174 and A1 R170, repeat steps 2 and 3 above until readouts are as specified without additional adjustment.

5-24. Analyzer Adjustments.

a. Procedure.

1. Set TMA 3000 in FLUTTER mode, 200 KHz REF FREQ, 20 KHz LPF BW, 2 Sigma, and 10% Meter Range.

2. Connect REF FREQ output (bnc) to FLUTTER TBE/SKEW input (bnc) with short bnc-to-bnc coaxial jumper cable.

3. Inject 5.00 KHz signal into test point A5 TP2 of D-Mod board (A5 TP0 is signal ground). Adjust signal level as necessary to produce full-scale reading on measurement pp meter (i.e., 10%).

4. Select ANA mode and 2 to 20 KHz ANA RANGE.

5. Carefully adjust analyzer center frequency to 5.00 KHz.

6. Adjust interconnect board potentiometer A1 R171 to peak TMA analog meter reading.

7. Verify that measurement pp meter peak reading is at 10% (full scale). If meter reading is not at full scale adjust interconnect board potentiometer A1 R167 to produce exactly full-scale (10%) indication.

8. Select INPUT mode. Adjust oscillator to 100 Hz and adjust output level for exactly full scale (10%).

9. Select ANA mode and 10 to 200 Hz range.

10. Adjust front panel potentiometer to peak measurement pp meter reading. (FREQUENCY digital readout should be 100 ±5 Hz.)

11. Verify that peak measurement pp reading is 10% (full scale). If peak is not at full scale, adjust interconnect board potentiometer A1 R168 for 10% (full scale).

12. Press REM (remote) button. Verify that FREQUENCY meter digital readout is 205 Hz. If digital readout is not as specified, adjust interconnect board potentiometer A1 R169 for FREQUENCY readout of 205 Hz.

13. Disconnect jumper cable.

5-25. Input Channel Adjustment.

a. Procedure.

1. Place TMA 3000 in FLUTTER mode, 400 KHz REF FREQ, 20 KHz LPF BW, 2 Sigma, and 10% Meter Range.

2. Connect sine-wave oscillator (HP 651B or equivalent) to FLUTTER TBE/SKEW input.

3. Adjust oscillator to 400 KHz and output level to 40 millivolts rms.

4. Turn input Channel 1 trim potentiometer A2 R58 fully clockwise.

5. Visually observe 10% meter range indicator (LED) while slowly turning potentiometer A2 R58 counterclockwise until 10% range indicator begins to flash intermittently. (This sets input sensitivity to 40 millivolts.)

6. Verify sensitivity (A2 R58) adjustment by increasing input level (HP 651B output) to approximately 100 millivolts and then slowly reducing level until 10% range indicator just begins to flash intermittently. Verify that HP 651B oscillator output level is 40 ±4 millivolts.

7. Select SERVO mode and move HP 651B oscillator output to SERVO TBE/SKEW input.

8. Repeat steps 3 through 6, except in steps 4 through 6 observe 3 usec range indicator for intermittent flashing while adjusting A3 R58 of input channel 2 board.

9. Disconnect test setup.

5-26. Input Bandpass Filter Check.

a. Procedure.

1. Connect REF OUT connector to FLUTTER TBE/SKEW connector, using short length of bnc-to-bnc coaxial jumper cable.

2. Select FLUTTER mode, 400 KHz REF FREQ, FRONT, and any other desired condition.

3. Connect oscilloscope to rear panel BPF OUTPUT connector marked FLUTTER TBE/SKEW.

4. Verify that REF FREQ squarewave has been filtered and appears as a sinewave of approximately 3 volts pp amplitude.

5. Step down REF FREQ range, observing that each frequency is present, filtered, and approximately 3 volts pp amplitude.

6. Select SERVO mode and connect REF OUT connector to SERVO TBE/SKEW input. Monitor rear panel BPF OUTPUT connector marked SERVO TBE/SKEW.

7. Repeat steps 2 through 4.

8. Disconnect test setup.

5-27. Rear Panel Inputs.

a. Procedure.

1. Press BACK button (one of SOURCE group).

2. Connect REF OUT connector to rear panel connector marked FLUTTER TBE/SKEW using bnc-to-bnc coaxial jumper cable.

3. Select FLUTTER mode.

4. Repeat bandpass filter check (steps 2 through 4 of paragraph 5-26), except check with rear connectors.

5. Change REF OUT connection to SERVO TBE/SKEW rear connectors and repeat SERVO input check of paragraph 5-26 (steps 5 and 6).

6. Disconnect test setup.

5-28. Tracking Mode Test.

a. Procedure.

1. Connect external oscillator (HP 651B or equivalent) to rear panel FLUTTER TBE/SKEW input connector.

2. Adjust oscillator frequency to 400 KHz and output level to 100 millivolts rms.

3. Set TMA 3000 controls to select FLUTTER mode, BACK source, and reference frequency to TRACK function.

NOTE

TMA 3000 will set its REF FREQ to 400 KHz and acquire input signal within approximately 5 seconds; acquisition is indicated by valid (i.e., non-blanked) frequency readout display and steady (not flashing intermittently) METER RANGE indicator.

4. Change external oscillator frequency to 200 KHz and verify that new frequency is acquired.

5. Step down (down-arrow button) through frequency ranges and adjust external oscillator to any intra-range frequency within each range; verify that TMA 3000 will track changes in input frequency from range to range.

6. Set external oscillator frequency to 200 KHz and wait for TMA 3000 to acquire new signal (approximately 5 seconds, refer to Note in step 3).

7. Slowly increase external oscillator frequency adjustment until either RANGE indicator begins flashing or frequency meter readout blanks off. Verify that external oscillator frequency adjustment is set for 238 KHz or higher.

8. Disconnect test setup.

5-29. FLUTTER Noise Floor.

a. Procedure.

1. Press POWER pushbutton to off.

2. Re-install D-MOD board shield (removed in paragraph 5-16). Fasten shield in place, checking to ensure that shield is insulated from microprocessor mounting tray.

3. Fold microprocesor tray down and install two 8-32 screws to secure tray in place.

4. Connect REF OUT connector to FLUTTER TBE/SKEW connector, press POWER button to on and select: 400 KHz REF FREQ, 20 KHZ LPF BW, FLUTTER mode, and .01% METER RANGE (i.e., most sensitive setting).

5. Verify that indicated flutter is below half scale (0.005%).

6. Step down frequency range, verifying that indicated flutter does not exceed half scale in any range. (Typically, 100 KHz REF FREQ and 20 KHz LPF BW settings produce highest noise floor.)

7. Disconnect test setup.

5-30. INSTRUMENT REASSEMBLY. If no erroneous results occurred during the calibration procedures, operator confidence may be established in TMA 3000 being fully functional and meeting design specifications. The unit can now be reassembled.

a. Procedure.

1. Deenergize TMA 3000.

2. Check that all cables are secured before installing top cover. Install top cover and secure in place with screws.

3. Restore TMA 3000 to normal service readiness.

8-12. TMA COMMAND PROTOCOL.

8-13. Each command sent to a TMA 3000 consists of a string of ASCII characters that describe the required operation. Such commands can range from three characters to as many as 10 and may be strung together in a single sequence of up to 32 characters that are terminated by carriage return, line feed sequence (i.e., CRLF sequence, ASCII hexadecimal ØD, ØA, which counts as two characters). The individual commands in a sequence should be separated by spaces or commas.

8-14. Once the TMA 3000 has received command line termination, each command in the sequence is interpreted and executed in succession. Upon completion of execution of all commands in the sequence, the TMA 3000 issues a null string (ASCII CRLF) as acknowledgment. The default end-of-line sequence (EOL) is a carriage return (CR, ASCII hexadecimal 0D), but the controller may change the EOL to be a carriage return, line feed (CRLF, ASCII hexadecimal 0D, 0A) by issuing the "LF" command. Query commands, where the TMA 3000 must respond with a data message, will result in either the data message or an error message.

8-15. The remote controller must be programmed to receive an ASCII message of up to 40 characters in length following every command sequence. It is imperative that this message be received before another command is issued; failure to observe this requirement will result in a hangup (i.e., a malfunction, which results in a lockup in an illegal mode) in the TMA 3000, the controller, the data bus, or in all three areas. For similar reasons, only one query command may be present in each sequence, and that query must be the last command in the sequence. Generation of only one query in any command sequence ensures that only a single message or acknowledgment will be issued by the TMA 3000 in response to each command sequence.

8-16. Execution time periods for the various commands range from less than 160 milliseconds for most simple commands to about 3 seconds for the DIAG command. It is recommended that the response timeouts for inputs to the TMA 3000 be set for 1 second for normal commands and for 5 seconds for query commands. These timeout periods will provide sufficient time for the TMA 3000 to respond without hanging up the controller in a malfunction.

8-17. TMA COMMANDS.

8-18. The commands that are recognizable by the TMA 3000 are divided into four categories:

- o Commands that duplicate TMA 3000 front-panel control functions.
- o Commands that set values.
- o Commands that query the TMA 3000 for a data response.
- o The "LF" command that modifies the EOL sequence.

8-19. FRONT-PANEL FUNCTION COMMANDS. Commands that duplicate front-panel control functions are listed in table 8-1, Function Select Commands.

COMMAND	FUNCTION
TRACK	Selects frequency-tracking mode
@LPF	Selects auto low-pass filter mode
@METER	Selects auto-meter ranging
CAL/ON	Selects CAL mode - retains current FLUTTER/TBE setting
CAL/OFF	Deselects CAL mode
FLUTTER	Selects FLUTTER mode
TBE/SK	Selects TBE/Skew mode
SERVO	Selects Servo mode
1SIG 2SIG 3SIG	Selects statistical voltmeter SIGMA level
INPUT	Selects INPUT, deselects ANA
ANA	Selects ANA, deselects INPUT
FRONT	Selects FRONT panel data inputs
BACK	Selects BACK panel data inputs
VMR	Performs voltmeter reset to speed up meter settling
REM/ON	Inhibits front panel switches (other than REM)
REM/OFF	Enables front panel switches

Table 8-1. TMA 3000 Function Select Commands

8-20. SET VALUE COMMANDS. Since any remote computer is able to generate digital binary values directly, it is able to set reference frequency, filter band width, meter range, analyzer center frequency and range specifically without utilizing up and down arrow functions. Value commands are distinguished by an equal (=) sign (e.g., "RFREQ=400" or "METER=3.0"). Value commands are listed in table 8-2. There should not be spaces between characters in a command. Spaces or commas are used to separate the various commands when a series of commands is transmitted in a single line.

8-22. LF COMMAND. The command "LF" instructs the TMA 3000 to issue a CRLF sequence as end-of-line instead of the default CR only. Both sequences are commonly used in IEEE 488 applications, and the ability to select either makes it easier to integrate the TMA 3000 into existing installations. The LF command was added for serial numbers 30051 and up.

8-23. SELECTING RS-232C BAUD RATE.

8-24. When the optional RS-232C Interface is installed, the serial interface data rate, denoted as Baud rate, may be set by the operator to match most standard rates currently in use.

8-25. A four-position DIP switch is located on the RS-232C interface board and is accessible from the rear panel (just above the RS-232C connector). Table 8-4 lists the switch settings for each Baud rate. As a convenient reference, the corresponding clock frequency measured at test point TP1 of the interface board is also listed.

BAUD RATE	SWI-1	SWI-2	SWI-3	SWI-4	TP1 (kHz)
300	O	C	O	C	4.8
1200	O	O	O	C	19.2
2400	C	O	C	O	38.4
4800	C	C	O	O	76.8
9600	C	O	O	O	153.6

NOTE: O = open switch; C = closed switch.

Table 8-4. RS-232C Baud-Rate Selections

8-26. SELECTING IEEE 488 ADDRESS.

8-27. TMA 3000 units prior to serial number 30051 require the use of both a primary address between Ø and 31, and a secondary address of Ø for all IEEE 488 communications. In units with serial number 30051 and subsequent, the secondary address is optional. These units will respond to any secondary address at the assigned primary address, providing complete compatability with control software for earlier units.

8-28. Every device connected to an IEEE 488 bus must have a unique address. Accordingly, each TMA 3000 used in a test setup must have its own address selected by the user to match the address that the controller will use to command its operation. The TMA address is set by selecting the appropriate binary code on the 8-bit

DIP switch located above the IEEE 488 connector at the rear panel of the TMA 3000. Switches No. 1 (LSB) through 5 (MSB) may be set to any primary address from Ø (all switches open) to 31 (all switches closed). (Address Ø should be avoided as this is conventionally reserved for the bus controller.) If the TMA 3000 is operated with a controller, set switch No. 8 to closed (controller on line), and both switch 7 (TALK) and switch 6 (LISTEN) to open.

8-29. If no controller is on line, set switch No. 8 to open, switch No. 7 to open (TALK), and switch No. 6 (LISTEN) to closed. [In this mode (NO CONTROLLER ON LINE) these switch settings cause the TMA 3000 to execute any commands on the bus, but will disable data outputs and error messages.] In this mode, switches No. 6 and No. 7 are ENABLE switches (in the CONTROLLER ON LINE mode, these function as DISABLE switches).

8-30. Switches Ø through 5 specify the primary address (Ø through 31). An illustration of the address DIP switch settings, for example, address 7 in a system with a controller where both talker and listener modes are enabled, is shown in figure 8-1. The proper switch settings for any address between Ø and 31 are listed in table 8-5.

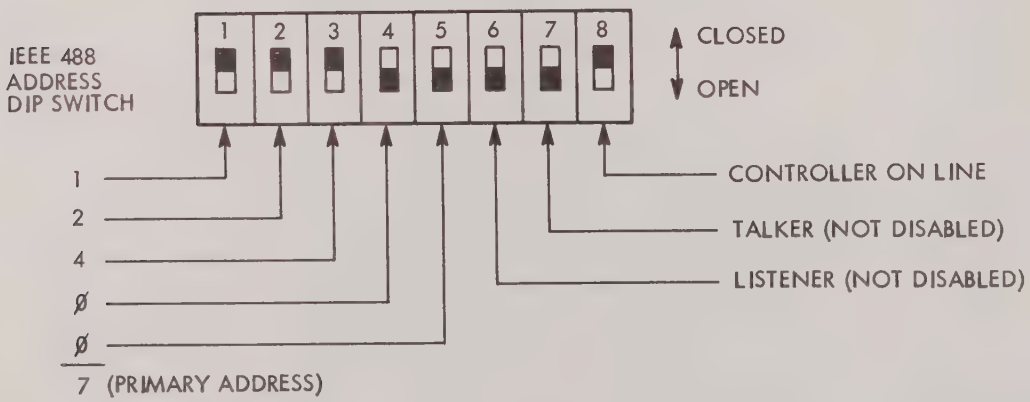


Figure 8-1. IEEE Addressing Example

SWITCH 1	2	3	4	5	ADDRESS	SWITCH 1	2	3	4	5	ADDRESS	SWITCH 1	2	3	4	5	ADDRESS
O	O	O	O	O	Ø	C	C	O	C	O	11	O	C	C	O	C	22
C	O	O	O	O	1	O	O	C	C	O	12	C	C	C	O	C	23
O	C	O	O	O	2	C	O	C	C	O	13	O	O	O	C	C	24
C	C	O	O	O	3	O	C	C	C	O	14	C	O	O	C	C	25
O	O	C	O	O	4	C	C	C	C	O	15	O	C	O	C	C	26
C	O	C	O	O	5	O	O	O	O	C	16	C	C	O	C	C	27
O	C	C	O	O	6	C	O	O	O	C	17	O	O	C	C	C	28
C	C	C	O	O	7	O	C	O	O	C	18	C	O	C	C	C	29
O	O	O	C	O	8	C	C	O	O	C	19	O	C	C	C	C	3Ø
C	O	O	C	O	9	O	O	C	O	C	2Ø	C	C	C	C	C	31
O	C	O	C	O	1Ø	C	O	C	O	C	21						

NOTE: O = open switch; C = closed switch

Table 8-5. Switch Settings for Primary Address

8-31. SPECIAL IEEE 488 FUNCTIONS.

8-32. The TMA 3000 is configured only for general communications; the TMA 3000 does not generate service requests (SRQ) nor does it respond to group trigger (GET). The parallel polling protocol is not implemented in the TMA 3000.

8-33. The DEVICE CLEAR bus command generates a full reset of the TMA 3000.

CAUTION

The TMA reset returns the TMA 3000 to its power-on state and clears the REMote status; the remote operation is then disabled and can only be restored by the operator manually pressing the REM pushbutton on the TMA front panel.

8-34. TMA STATUS DECODING.

8-35. In response to a STAT command, the TMA will return a string of four ASCII encoded hexadecimal bytes which represent the present status of the instrument. The machine status must be referred to in order to interpret the data which is returned in response to a DATA command. Hexadecimal is used to minimize the length of the data string and because it is easily converted from and to the binary used within the microprocessor.

8-36. Each of the status bytes contains from two to eight fields, each dedicated to some specific characteristic of operation. For example, BYTE 0 is composed of two fields, the first of which indicates the low pass filter bandwidth and the second the reference frequency. A typical BYTE 0 might be 87, representing a low pass filter setting of 20 KHz and a reference frequency of 100 KHz. BYTE 1 comprises eight individual bits indicating whether the automatic modes (Meter, Filter, Track), Cal, or Remote are on or off; whether the frequency indication is in Hz or KHz; which inputs are selected (Front or Rear); and whether the meter data is to be interpreted as time (Microseconds) or percent (Flutter).

8-37. Table 8-6 gives the information necessary to decode the full status return. Recall that the ADC data returned as part of the response to a DATA command is a fraction of full scale (205 is full scale). The actual data reading is obtained by dividing the ADC data by 205 and multiplying by the meter range.

8-38. A typical status response might be:

78EFE404 <CRLF>

signifying:

78	10 KHz Filter Bandwidth, 200 KHz Reference Frequency
E	Auto Meter On Auto Filter On Track On Cal Off
F	Remote On KHz Front Inputs Meter reads Microseconds
E	Frequency meter reads the Input frequency Time Base Error 2 Sigma
4	1.0 (Microsecond) Full Scale
0	These bits not used
4	XXX.XX Frequency Meter Display (eg, 200.00) Frequency Display not on hold

8-39. COMMUNICATION PROGRAMS FOR TMA 3000.

8-40. The programs in tables 8-7 and 8-8 provide for communication between the Commodore PET or Hewlett-Packard HP-87 computer and the TMA 3000. It is essential that the TMA 3000 be able to respond instantly to some commands from the computer or take considerably longer to respond to DATA and DIAG queries. DATA queries have to wait for the next data update. DIAG queries have to wait for a measurement sequence which may take several seconds. The TMA 3000 is rather inflexible in that it will hang up if there is not sufficient time to send its response.

8-41. TMA 3000 ADDRESSING. The TMA 3000 address switches should be set in accordance with paragraph 8-26 and figure 8-1.

8-42. TMA 3000 CLEARING. As stated previously, the TMA 3000 may hang up and generate an error message if not allowed to respond to queries. Clear a hang up by pressing the REMote switch to go out of the remote mode. Press REMote once more to return to the remote mode.

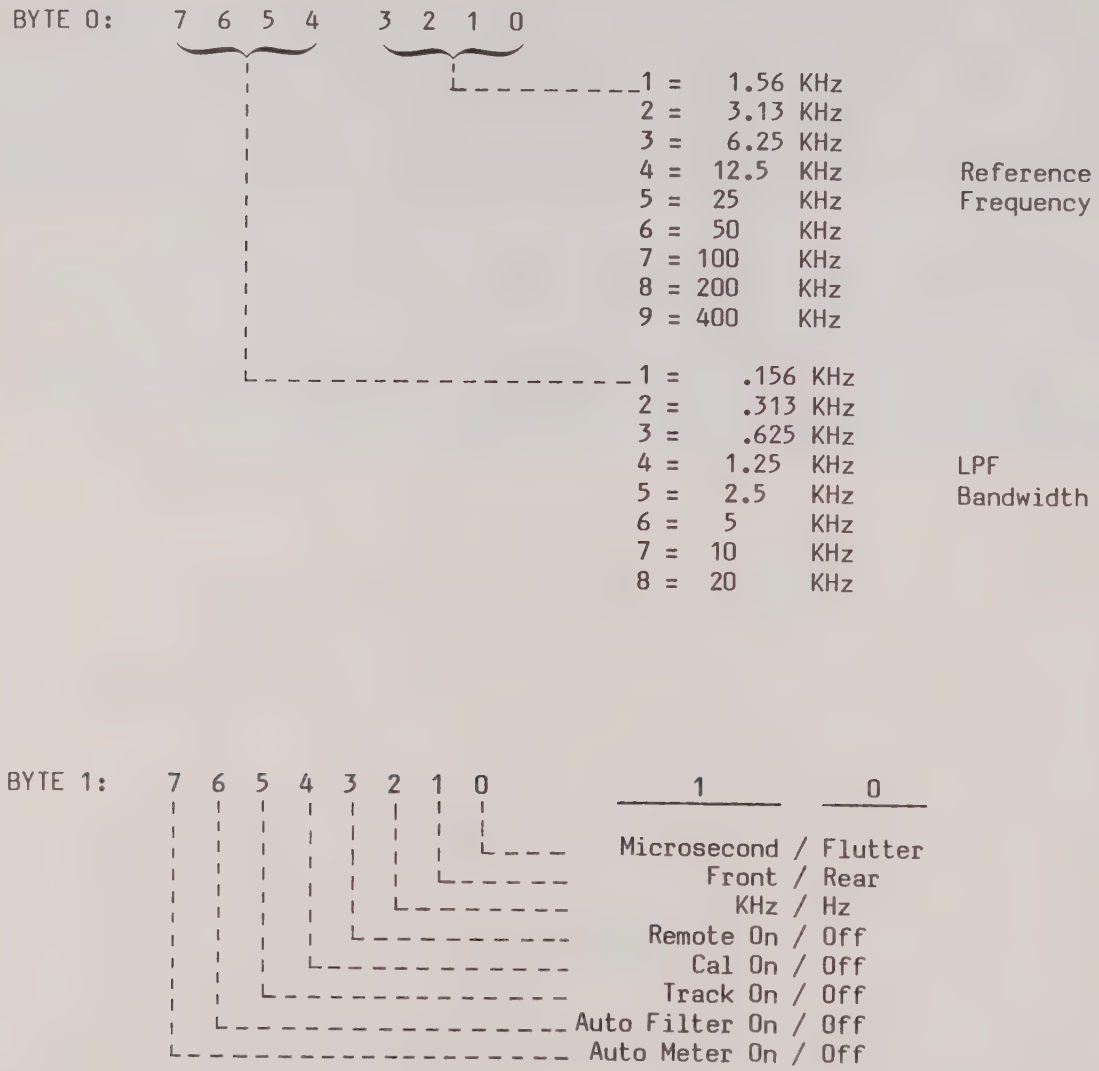


Table 8-6. Status Decoding (Sheet 1 of 2)

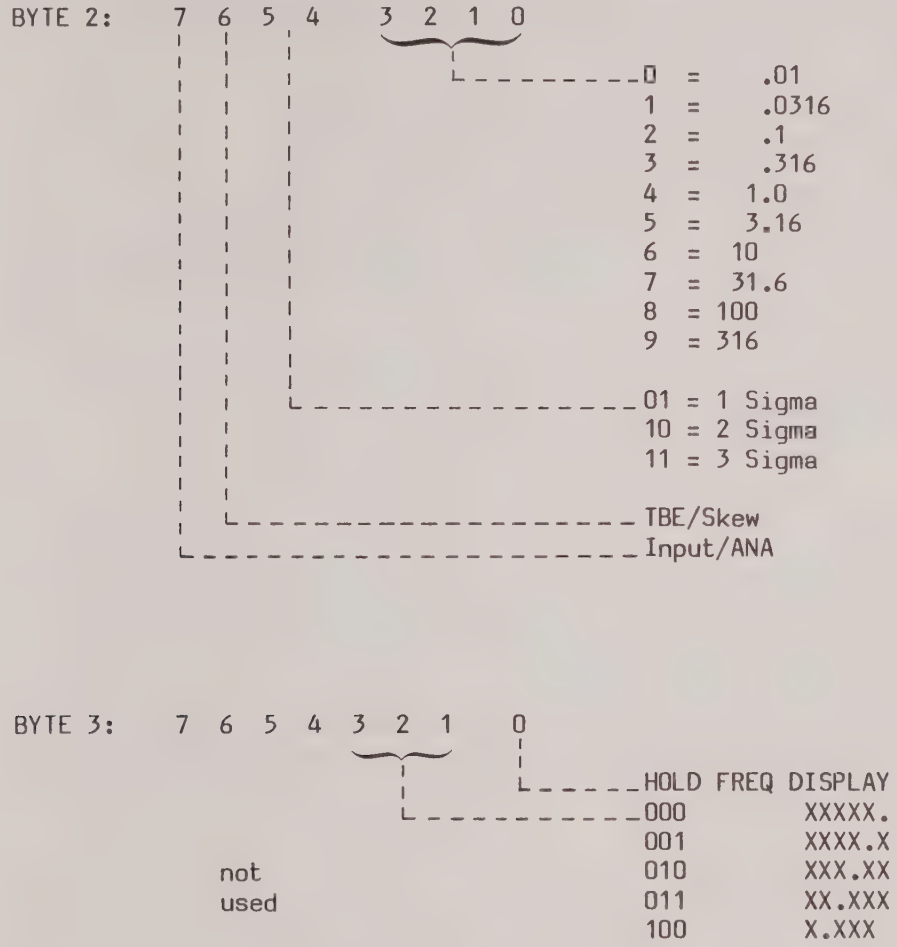


Table 8-6. Status Decoding (Sheet 2 of 2)

```
10 REM Interactive communications program for Commodore PET to be used
15 REM as tester for TMA-3000.
20 OPEN 5,7 REM Open as device 7 with no secondary address.
30 DIM M$(32),A$(32) REM Allow for maximum message length.
100 INPUT "MESSAGE"; M$ REM get message to be sent to TMA.
110 IF M$="D" THEN 140 REM Use D to indicate that data will be returned.
115 REM A longer timeout will be implemented for statements that request data.
120 GOSUB 300
130 GOTO 100 REM Loop back after completing communication.
140 INPUT "DATA MESSAGE";M$
150 GOSUB 400
160 GOTO 100
300 PRINT#5, M$ REM You MUST spell out "PRINT" when specifying a logical
305 REM device.  The "?" short cut works only when printing to the screen.
310 For I=1 TO 10 REM Uses PET's internal IEEE 488 timeout (~64 mSec*10)
320 INPUT#5, A$ REM Get response from TMA
330 IF ST=2 THEN NEXT I REM ST=2 indicates interface timeout (64 mSec)
340 IF A$=" " THEN RETURN REM "null" string (space) indicates acceptance of
345 REM command.
350 PRINT A$
360 A$=" " REM Reset A$ to null string.
370 RETURN
400 PRINT#5, M$
410 FOR I=1 TO 100 REM 6.4 Second timeout (DIAG can take several seconds).
420 INPUT#5, A$
430 IF ST=2 THEN NEXT I
440 IF A$=" " THEN RETURN
450 PRINT A$
460 A$=" "
470 RETURN
```

Table 8-7. Commodore PET Communication Program

```
10 REM Interactive communications program for HP-85 or HP-87
20 REM computer to be used as tester for TMA-3000
30 DIM A$[40]
40 DIM M$[40] ! Dimension strings to TMA I/O buffer capacity.
50 RESET 7 ! Reset interface.
60 CLEAR ! Clears CRT
70 DISP "SYSTEM HAS RESTARTED"
80 ON TIMEOUT 7 GOTO 50 ! Restart program if interface times out.
90 SET TIMEOUT 7;10000 ! Timeout=10 seconds.
100 M$="LF" @GOTO 120 ! Set TMA for CRLF as EOL sequence.
110 DISP "MESSAGE"; @INPUT M$; ! Input the message to be sent to TMA.
120 SEND 7; CMD "U?'" DATA M$ EOL ! Send message.  NOTE:  TMA address is 7
130 WAIT 500 ! Allow .5 second for TMA to process command.
140 SEND 7; UNL MLA TALK 7 ! Address TMA as talker, listen for response.
150 ENTER 7; A$ ! Get the response.
160 IF A$=" " THEN GOTO 180 ! If null string (SPACE, CR, LF), don't display.
170 DISP "INTERFACE SAYS";A$ ! Display the response.
180 A$=" " ! Clear A$ before sending another message.
190 GOTO 110 ! Loop around again.
200 END
```

Table 8-8. Hewlett-Packard HP-85 or HP-87 Communication Program

LIST OF EFFECTIVE PAGES

Title Page 992776
List of Effective Pages 05-83
Pages i through iv 05-83
Pages 1-1 through 1-5 05-83
Page 1-6 Blank
Pages 2-1 through 2-3 05-83
Page 2-4 Blank
Pages 3-1 through 3-17 05-83
Page 3-18 Blank
Page 4-1 through 4-16 05-83
Pages 5-1 through 5-30 05-83
Pages 6-1 through 6-40 05-83
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Page 7-31 05-83
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SECTION I

GENERAL INFORMATION

1-1. SCOPE OF MANUAL.

1-2. This technical manual provides installation and operating instructions for the TMA 3000 Tape Motion Analyzer. Information contained in this manual is for use by experienced technical personnel involved in the actual operation of the subject equipment.

1-3. ARRANGEMENT.

1-4. Information in this manual is arranged in eight sections, as follows:

Section I General Information

Section II Installation

Section III Operating Instructions

Section IV Functional Description

Section V Maintenance Instructions

Section VI Illustrated Parts Breakdown

Section VII Schematics

Section VIII Remote Control Options

1-5. APPLICABILITY.

1-6. The instructions contained in this manual apply to the TMA 3000 Tape Motion Analyzer only, identified by Bell & Howell part number 552100. Differences, if any, between this equipment and the actual equipment supplied are covered in the Change Notice immediately preceding this section.

1-7. EQUIPMENT DESCRIPTION.

(Figure 1-1)

1-8. The TMA 3000 Tape Motion Analyzer is used to measure and diagnose tape motion irregularities in magnetic tape recorders. The TMA 3000 measures the following basic tape variations:

a. Flutter is the short-term variation of tape speed, expressed in percent pp.

b. Time base error is the short-term time displacement variations between events recorded on tape and real time, expressed in microseconds pp.

c. Servo time base error is a special case of time base measurement where two quantities to be measured are represented by alternate zero crossings of a square wave. This time base error is the variation, expressed in microseconds pp, of the square wave duty cycle.

d. Dynamic skew is the apparent short-term time displacement variations between different tracks on the tape. Skew, expressed in microseconds pp, is generally caused by the twisting or snaking motions of the tape.

e. Drift is the longer term variations of tape speed. Drift is not measured directly, but is indicated by measuring the reproduced frequency of a precision reference signal recorded on tape.

1-9. With the exception of drift, each of the above measurements can be made over a limited frequency range (up to one-fifth of the reference frequency in binary multiples of 156 Hz) and with operator-defined meter statistics (1σ, 2σ, 3σ). A built-in wave analyzer, tunable from 0.2 Hz to 10 kHz, allows precise assessment of specific frequency components.

1-10. The TMA 3000 conforms to the requirements and the intent of the Inter-Range Instrumentation Group (IRIG) specifications 106-80 and 118-79 for tape recorder flutter measurements. The design of the TMA 3000 utilized these same standards to develop time base and skew measurements, capabilities previously unavailable.

1-11. Optional computer interfaces (IEEE 488 and RS-232C) are available with the TMA 3000 to allow all functions and capabilities (including meter reading) to be remotely accessible. This feature makes the TMA 3000 ideal for integration into automatic test equipment.

1-12. Additionally, as a precision low-noise frequency demodulator, the TMA 3000 can be used in the testing of motors, gear trains, incremental encoders, and oscillators. The skew and time base measurements of the TMA 3000 are useful for evaluating digital tape transports and phase lock loops.

4008-1

Figure 1-1. TMA 3000 Tape Motion Analyzer

1-13. REFERENCE DATA.

(Table 1-1)

1-14. Equipment specifications and performance characteristics are listed in table 1-1.

ITEM	CHARACTERISTIC
ELECTRICAL CHARACTERISTICS	
Power Requirements	115 V ac ±10 percent, 48-420 Hz, single phase (or 230 V ac).
Electrical Protection	1 amp slow-blow fuse on high side of input line for 115 V ac operation (0.5 amp slow-blow for 230 V ac configuration).
PERFORMANCE SPECIFICATIONS	
Reference Frequencies	1.56, 3.13, 6.25, 12.5, 25, 50, 100, 200, 400 kHz, ±0.01 percent.
Low Pass Filter Bandwidths	0.156, 0.313, 0.625, 1.25, 2.5, 5, 10, 20 kHz.
Frequency Meter	10 Hz resolution; ±0.01 percent accuracy.
Flutter Measurements	IRIG standard 9 tape speeds: 15/16 to 240 ips.
Flutter Ranges, Full Scale	0.01, 0.03, 0.1, 0.3, 1, 3, 10 percent pp.
Time Base Error Ranges, Full Scale	0.3, 1, 3, 10, 30, 100, 300 microsec pp.
Measurement PP Meter	0 to 1 and 0 to 3.16 scales.
Sigma Levels	1σ (exclude peaks occurring < 32 percent of time). 2σ (exclude peaks occurring < 5 percent of time). 3σ (exclude peaks occurring < 0.3 percent of time).
Operating Environment	0° to 55°C. 5 to 95 percent relative humidity (non-condensing).

Table 1-1. Specifications and Performance Characteristics (Sheet 1 of 2)

ITEM	CHARACTERISTIC
INPUT POWER REQUIREMENTS	
Power Input	50 VA maximum.
INPUTS - Front Panel	
FLUTTER TBE/SKEW	Flutter input, used in TBE/SKEW.
SERVO TBE/SKEW	Servo input, used in TBE/SKEW.
Sensitivity	50mV rms to > 10V rms. Inadequate signal level results in flashing LED in meter range.
INPUTS - Rear Panel	
FLUTTER TBE/SKEW SERVO TBE/SKEW	Identical inputs on rear panel are selectable by front panel switch, from interface, or automatically in TRACK mode.
OUTPUTS - Front Panel	
REF OUT	Square wave at selected reference frequency; level is nominally 3V pp into 50 ohms from 50-ohm source. Internal adjustment permits setting reference level over approximately 0.5V pp to 5V pp into 50 ohms.
DEMOD OUT	Analog output for monitoring signal being measured by statistical voltmeter. Calibrated output level is 1V pp for full scale meter deflection. Source impedance 600 ohms.
OUTPUTS - Rear Panel	
BPF OUTPUTS FLUTTER TBE/SKEW SERVO TBE/SKEW	Two analog outputs. Each output is the respective input after leveling (~3V pp) and filtering in the input channel conditioner. Input filter characteristics are approximately -10, +20 percent around nominal reference frequency.
PHYSICAL CHARACTERISTICS	
Height	3.75 inches.
Width	17 inches.
Depth	13.25 inches.
Weight	14 pounds 5 ounces.

Table 1-1. Specifications and Performance Characteristics (Sheet 2 of 2)

1-15. OPTIONS AND ACCESSORIES.

1-16. The following options and accessories are available for the TMA 3000:

a. Carrying Case, PN 552117.

b. Rack Mount Adapter, PN 552116.

c. IEEE 488 Interface, PN 552114.

d. RS-232C Interface, PN 552115.

1-17. ABBREVIATIONS.

1-18. The abbreviations used in this manual are as follows:

ABBR	MEANING
A/D	Analog to digital
AFC	Automatic frequency control
AGC	Automatic gain control
ANA	Analyzer
ATE	Automatic Test Equipment
BPF	Band pass filter
BW	Bandwidth
CAL	Calibrator/Calibration
CMOS	Complementary metal oxide semiconductor
Cont	Continued
DAC	Digital-to-analog converter
DCE	Data Communications Equipment
D-MOD	Demodulator
DTE	Data Terminal Equipment
EMI	Electromagnetic interference
FM	Frequency modulation
Freq	Frequency
IC	Integrated circuit
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/output
IPS	Inches per second
IRIG	Inter-Range Instrumentation Group
LED	Light emitting diode
LPF	Low pass filter
PP	Peak-to-peak
RAM	Random access memory
Ref	Reference
Rem	Remote
Rep	Reproduce
ROM	Read only memory
SNR	Signal-to-noise ratio
TBE	Time base error
TMA	Tape Motion Analyzer
VOM	Volt ohm milliameter
σ	Sigma

SECTION II

INSTALLATION

2-1. SCOPE OF SECTION.

2-2. This section contains information and instructions for installing the TMA 3000 Tape Motion Analyzer.

2-3. SPECIAL TOOLS AND SUPPORT EQUIPMENT.

2-4. No special tools or support equipment are required for the installation of the TMA 3000 unit, except for optional adapters for rack mounting. These adapters are listed in Section I.

2-5. POWER REQUIREMENTS.

2-6. The TMA 3000 power requirements are either 115 V ac +10 percent single phase or 230 V ac at 48 to 420 Hz. The unit uses a 1 ampere, 250 V 3AG slow-blow fuse on the high side of the input line for 115 V ac operation. A 0.5 ampere fuse is recommended for 230 V ac operation.

2-7. INSTALLATION.

2-8. The TMA 3000 operates as a bench mounted instrument or as a unit installed, with optional rack mount adapters, in a standard 19-inch rack. The following procedures should be observed before operating the TMA 3000 unit.

CAUTION

The TMA 3000 instrument could be severely damaged if the unit is set for 115 V ac and operated with 230 V ac.

a. Verify that the power selector switch on rear panel is set to the proper line voltage.

NOTE

When the power switch is set at 230 V ac, the TMA 3000 will not operate with 115 V ac power line voltage.

b. Verify that cooling vents in top and bottom covers of instrument are not blocked.

NOTE

The TMA 3000 has no special cooling or orientation requirements. However, like all electronic equipment, it produces some heat which should be allowed to vent out.

c. If a computer interface option (IEEE 488 or RS-232C) is to be used, attach cable to connector on rear panel and set corresponding dipswitch (see Section III).

NOTE

Input and output cables may be attached at this time to the front or rear panel connectors of TMA 3000 (see Section III).

d. For rack mounting, perform the following procedures to install rack mount adapters onto TMA 3000 unit (refer to figure 2-1):

1. Pry trim plates out of front of side castings, using a small knife. (These plates are held in place by a light adhesive.)

2. Attach rack mounting brackets to sides of instrument by inserting supplied screws into exposed Tinnerman nuts and tighten screws.

3. Install TMA 3000 into rack and secure with screws through slots of mounting brackets.

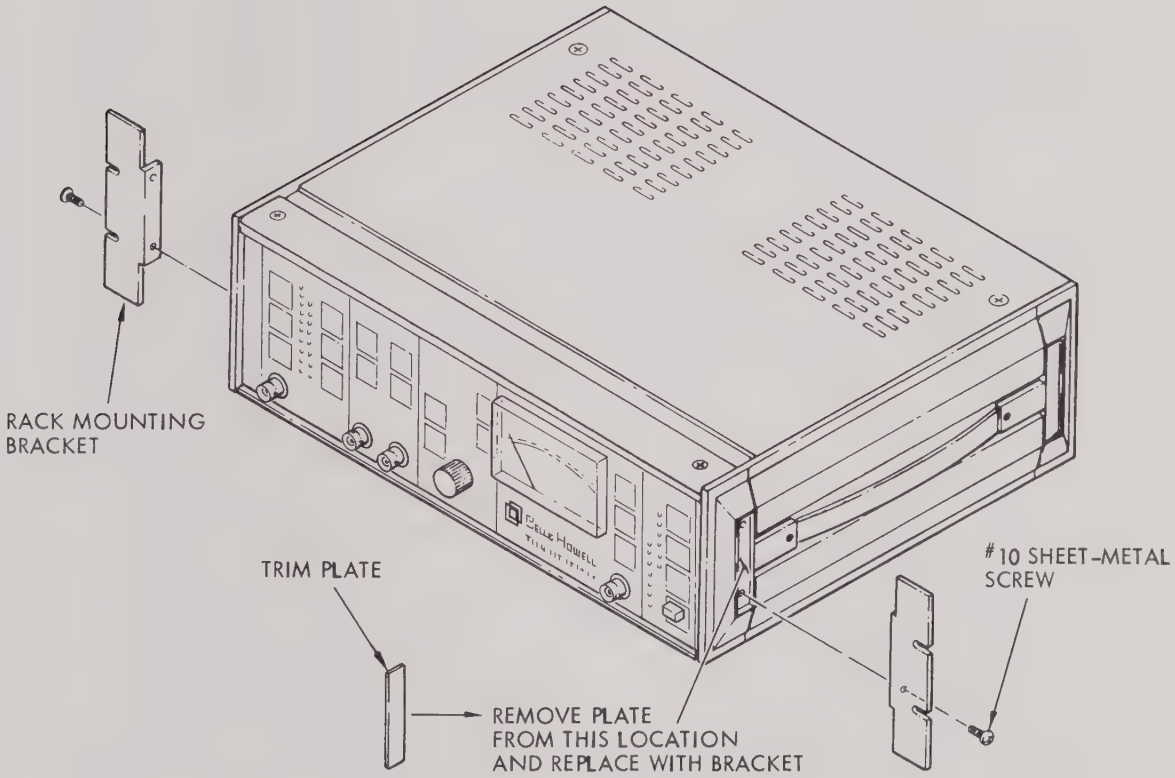


Figure 2-1. Typical Installation of Rack Mount Adapter

SECTION III

OPERATING INSTRUCTIONS

3-1. SCOPE OF SECTION.

3-2. This section presents the controls, indicators, and connectors of the TMA 3000 and the operating instructions for the instrument.

3-3. CONTROLS, INDICATORS, AND CONNECTORS.

3-4. Table 3-1 presents the controls, indicators, and connectors on the front and rear panels of the TMA 3000. The table starts with the front panel from left to right as illustrated in figure 3-1, which shows the location of each. A brief description is given for each in the table; refer to the operating instructions for their functional usage.

3-5. Also on the rear panel, if one of the computer interface options is selected, is the corresponding connector (in the middle of the rear panel). If the IEEE 488 connector is used, an eight-position dipswitch is located directly above the connector. This dipswitch is used to assign a bus address to the TMA 3000 and to enable/disable listener and/or talker functions. If the RS-232C connector is used, a four-position dipswitch is used to set the serial interface baud rate.

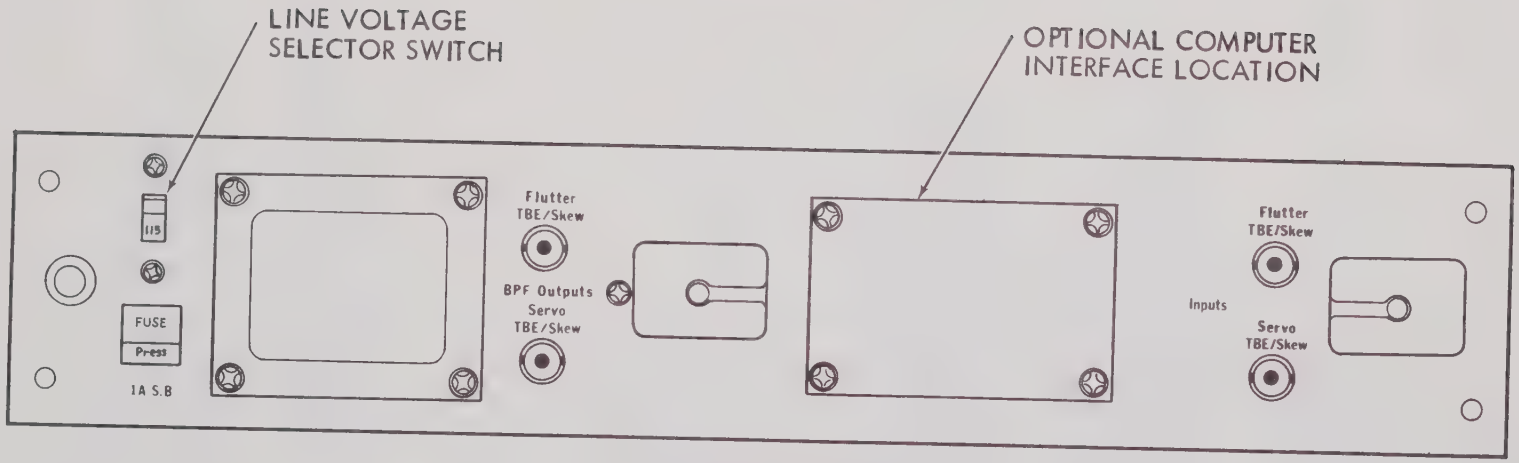
3-6. OPERATION.

3-7. The TMA 3000 provides five measurement modes to operationally check out a magnetic tape recorder:

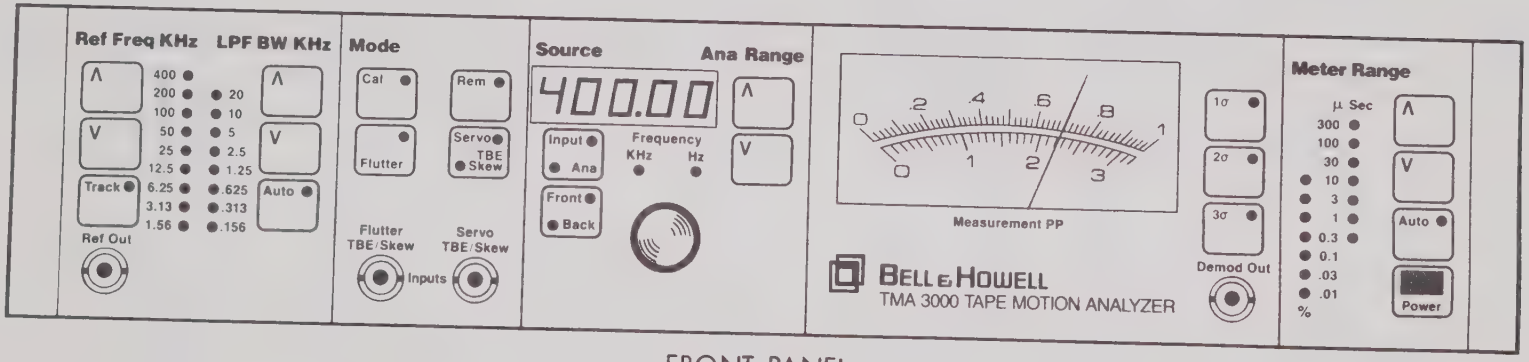
- o Flutter Mode Using Simultaneous Record/Reproduce
- o Flutter Mode Using Pre-Recorded Tape
- o Time Base Error Mode Using Tape
- o Time Base Error Mode Using Servo Mode
- o Skew Mode (Time Displacement Errors)

3-8. In addition, the TMA 3000 offers a calibration mode to check the operation of the instrument, and an analyzer mode for use in conjunction with the measurement modes. An optional remote mode is available for operation with an external control unit.

3-9. This subsection discusses some general operational information, features, and recommendations applicable to these measurement modes; briefly describes each measurement mode; and then presents the operating procedure for the measurement modes with individual setup information provided in separate illustrations.



REAR PANEL



FRONT PANEL

Figure 3-1. TMA 3000 Controls, Indicators, and Connectors

SECTION	CONTROL	INDICATOR	FUNCTION
		FRONT PANEL	
REF FREQ KHz	^		Increments reference frequency.
	v		Decrements reference frequency.
	TRACK		Sets track mode, where TMA follows input frequency.
		TRACK	Lights to show TMA is in TRACK mode.
		400, 200, 100, 50, 25, 12.5, 6.25, 3.13, 1.56	Lights (1 of 9 LEDs) to indicate selected reference frequency.
	REF OUT (BNC coaxial connector)		Provides a very low flutter square wave at the nominal reference frequency.
LPF BW KHz	^		Increments low pass filter (LPF) bandwidth.
	v		Decrements low pass filter bandwidth.
	AUTO		TMA automatically selects IRIG LPF bandwidth corresponding to selected reference frequency.
		AUTO	Lights to show that TMA is in AUTOLPF mode.
		20, 10, 5, 2.5, 1.25, .625, .313, .156	Lights (1 of 8 LEDs) to indicate selected LPF BW.
MODE	CAL	CAL	Switch/indicator to select CALibrate mode.
	FLUTTER	FLUTTER	Switch/indicator to select FLUTTER mode.

Table 3-1. Controls, Indicators, and Connectors (Sheet 1 of 5)

SECTION	CONTROL	INDICATOR	FUNCTION
		FRONT PANEL (CONT)	
	REM	REM	Switch/indicator to select REMote mode.
	SERVO	SERVO	Switch/indicator to select SERVO mode.
	TBE/SKEW	TBE/SKEW	Switch/indicator to select TBE/SKEW mode.
INPUTS:			
	FLUTTER TBE/SKEW (BNC coaxial connector)		Used as the signal input when measuring FLUTTER or as one of the inputs when measuring TBE or SKEW.
	SERVO TBE/SKEW (BNC coaxial connector)		Used as the signal input when measuring TBE in the SERVO mode or as one of the inputs when measuring TBE or SKEW.
SOURCE	INPUT/ANA	INPUT/ANA	Alternate action switch/indicator to select the INPUT (normal) or the ANAlyzer as the source of measurement signals.
	FRONT/BACK	FRONT/BACK	Alternate action switch/indicator to select either front panel or rear panel input(s) to be measured.
	FREQUENCY		Sets the analyzer center frequency.
		000.00 (5-digit display)	Indicates (to 10 Hz resolution) the frequency being measured, or in ANAlyzer mode, the center frequency of analyzer.
		KHz	Lights to indicate that FREQUENCY display is in kHz.

Table 3-1. Controls, Indicators, and Connectors (Sheet 2 of 5)

SECTION	CONTROL	INDICATOR	FUNCTION
		FRONT PANEL (CONT)	
		Hz	Lights to indicate that FREQUENCY display is in Hz.
ANA RANGE	^		Increments ANAlyzer range when in ANA mode.
	v		Decrements ANAlyzer range when in ANA mode.
MEASUREMENT PP METER		METER (analog)	Indicates flutter or TBE on either a 0-1 or 0-3.16 scale.
	1σ	1σ	*Switch/indicator to select 1σ characteristic for statistical voltmeter; ignores random peaks occurring less than 32% of the time.
	2σ	2σ	*Switch/indicator to select 2σ characteristic for statistical voltmeter; ignores random peaks occurring less than 5% of the time.
	3σ	3σ	*Switch/indicator to select 3σ characteristic for statistical voltmeter; ignores random peaks occurring less than 0.3% of the time. (It is, for all practical purposes, a true pp measurement.)
	DEMOD OUT (BNC coaxial connector)		Sources the analog output of the demodulator for monitoring purposes. If ANA is selected, the analyzer output is connected to DEMOD OUT.

*Pressing a lighted sigma button performs (without affecting any other condition) a reset of the measurement channel, clearing out-of-range meter indications caused by transients, momentary signal losses, etc.

Table 3-1. Controls, Indicators, and Connectors (Sheet 3 of 5)

SECTION	CONTROL	INDICATOR	FUNCTION
		FRONT PANEL (CONT)	
METER RANGE		% (left column) 10, 3, 1, 0.3, 0.1, .03, .01	Lights (1 of 7 LEDs) to indicate the selected meter range (in percent PP) when in the FLUTTER mode.
		μSec (right column) 300, 100, 30, 10, 3, 1, 0.3	Lights (1 of 7 LEDs) to indicate the selected meter range (in microseconds PP) when in the SERVO or TBE/SKEW modes.
	^		Increments meter range.
	v		Decrements meter range.
	AUTO	AUTO	Switch/indicator to select the AUTO meter ranging capability.
	POWER		Switch to turn power on/off to unit. Alternate action (push-push.)
		REAR PANEL	
INPUTS	FLUTTER TBE/SKEW (BNC coaxial connectors)		Alternate inputs to front panel (rear inputs are selected by the FRONT/BACK switch on the front panel).
	SERVO TBE/SKEW (BNC coaxial connectors)		
BPF OUTPUTS	FLUTTER TBE/SKEW (BNC coaxial connectors)		To provide the levelled, filtered signals of the respective inputs.
	SERVO TBE/SKEW (BNC coaxial connectors)		

Table 3-1. Controls, Indicators, and Connectors (Sheet 4 of 5)

SECTION	CONTROL	INDICATOR	FUNCTION
		REAR PANEL (CONT)	
LINE VOLTAGE	230 115		Switch to select either 115 V ac or 230 V ac line voltage to be used by the TMA 3000.

Table 3-1. Controls, Indicators, and Connectors (Sheet 5 of 5)

3-10. GENERAL INFORMATION.

3-11. Flutter and time base error (TBE) are very sensitive to the signal-to-noise ratio (SNR) of the record/reproduce channel. In modern low-flutter tape transports, reproduce noise can play a significant part in the measured flutter unless every opportunity is taken to increase the measurement SNR. It is strongly recommended that reference signal recordings be made at or near saturation level on bulk degaussed tape. IRIG 118-79 recommends recording at 13 dB above normal (1 percent 3rd) record level. The TMA 3000 REF OUT square wave is nominally 3V pp terminated into 50 ohms, but an internal adjustment potentiometer (R156 on interconnect board) allows the reference level to be adjusted over the range of approximately 0.5 to 5V pp.

3-12. The TMA 3000 input channel employs an automatic gain control to optimize signal levels in its band pass filters and limiters. Nonetheless, a signal level of 1 VRMS or greater is recommended for best results.

3-13. An excellent discussion of the interaction between SNR and flutter measurements is given in the IRIG Document 118-79, Test Methods for Recorder/Reproducer Systems and Magnetic Tape (Volume III).

3-14. The input channel conditioning continuously monitors the input signal to ensure that the inband (within about $\pm$20 percent of the reference frequency) signal component is large enough to ensure good limiting and that no out-of-band signals large enough to disturb the demodulators are present. If these conditions are not met, the input channel is disabled, the frequency meter indicates zero frequency, and the RANGE LED flashes to signify an erroneous reading. As soon as a valid input signal is encountered, the frequency meter indicates its frequency, and valid measurements result.

3-15. The flutter demodulator features automatic frequency control, and is able to track carrier frequencies from about 10 percent below nominal to about 20 percent above nominal without degradation in measurement accuracy. This feature enables errorless readings on flutter tapes recorded at IRIG Intermediate Band FM frequencies (216 kHz at 120 ips, etc). Flutter AFC also eliminates measurement errors when observing frequencies that do not correspond to the IRIG servo values. Such conditions often occur in testing motors, audio recorders, disc drives, and most non-telemetry equipment. Carrier frequencies which are beyond the demodulator tracking range will generally not pass through the input channel filters, or will result in an out-of-range indication (flashing RANGE LED).

3-16. Input frequency compensation is not necessary in the TBE circuits, although the measurement range is restricted. If the TBE range is exceeded, the out-of-range indication will occur.

3-17. FLUTTER MODE USING SIMULTANEOUS RECORD/REPRODUCE. (Figure 3-3.)

3-18. This mode is generally used as a quick check of recorder operation or as a diagnostic. Since the reproduction is being made on the same tape pass as the recording, the readings obtained are generally slightly better than those obtained playing back a pre-recorded tape. However, the convenience of interactive measurements in making adjustments and instantaneous results makes this mode the most frequently used. This technique should be used in making pre-recorded test tapes to monitor the recording quality.

3-19. FLUTTER MODE USING PRE-RECORDED TAPE. (Figure 3-4.)

3-20. This mode is the one used for acceptance tests and for measurement of the overall system flutter. The TRACKing and AUTOmatic functions of the TMA 3000 can be used in this mode to allow flutter reading loggings as tape speed is changed.

3-21. TIME BASE ERROR (TBE) MODE USING SERVO FROM TAPE. (Figure 3-5.)

3-22. This mode measures the pp time variations between the servo reference and the tape signal used in the reproduce servo mode. This operation mode duplicates the IRIG method for acceptance tests. IRIG allows the use of a narrow band filter (fc $\pm$5 percent) between the reproduce output and the measurement equipment. In instances where reproduce system noise is significant, such a filter could result in somewhat lower readings.

3-23. The TMA 3000 TBE measurement range is limited to static plus dynamic displacement of about $\pm$80 percent of the reference frequency period. Repetitive peaks outside this range will result in an error indication (RANGE LED flashing) and incorrect measurements.

3-24. TIME BASE ERROR (TBE) USING SERVO MODE. (Figure 3-6.)

3-25. Some tape recorders (such as the Bell & Howell VR3700 series and System J) generate a duty-cycle modulated square wave whose leading edge is derived from the reference oscillator and whose trailing edge comes from the reproduce control track or the capstan optical encoder. The SERVO mode affords a quick method to check system performance by looking at the servo error signal. This operation does not conform to the IRIG requirements, however, and is subject to errors if risetimes are not very fast and duty cycles depart significantly from 50 percent. The SERVO mode is recommended primarily for comparative purposes.

3-26. DYNAMIC SKEW MODE. (Figure 3-7.)

3-27. Skew measurements are performed in an identical manner to TBE (actually TBE may be considered a special case of skew) except that neither channel is a "reference." The measurement is a true differential between channels.

3-28. Skew perturbations tend to occur at low rates; for example, a major source of skew is the wobble in tape reels. The wobble rate may be as low as 1/50 times the tape speed in inches. The TMA 3000 measurement channel lower cutoff frequency (high pass) is slightly less than 0.5 Hz, and may produce lower skew readings (particularly at speeds less than 30 ips) than would result from the traditional oscilloscope methods.

3-29. CALIBRATION MODE. (Figure 3-2.)

3-30. In the calibration mode, a signal generated internally from the crystal controlled reference oscillator is applied to the channel input(s). If CAL (calibration) is entered from the FLUTTER mode, the calibration signal is 25 kHz modulated exactly 10 percent pp by a square wave at 195 Hz. If CAL is entered from TBE/SKEW mode, the calibration signal is two 25 kHz square waves whose time displacement is modulated exactly 10 usec pp at the same 195 Hz rate. By applying the signals at the input channels, virtually all of the TMA 3000 flutter and TBE channels are checked (input, demodulator, statistical voltmeter, frequency meter, analog meter, and by implication, the microprocessor). In the CALibrate mode, 1σ is automatically selected to minimize the effects of square wave overshoot in the low pass filters. In the FLUTTER CAL mode, the effective frequency applied is slightly above 25.000 KHz, and a meter reading of 25.04 to 25.09 may be observed. In the TBE/SKEW CAL mode, the observed frequency will be exactly 25.00 KHz.

3-31. The calibration signals are generated digitally from the 8 MHz crystal clock, with all signal timing directly (and synchronously) derived from the crystal. Calibration signal accuracy is inherently $\pm$0.01 percent with no adjustment required or possible.

3-32. The CALibrate mode is actually a calibration check, with no adjustments performed automatically. Rather, it serves as a confidence check to demonstrate accurate operation or to disclose measurement errors. A reading which differs from full scale by more than $\pm$3 percent indicates possible problems; an error greater than $\pm$5 percent is out of calibration and implies that service is required.

3-33. ANALYZER.

3-34. The built-in wave analyzer may be used to observe individual frequency components of the flutter or TBE/SKEW measurement in progress. Logically, the analyzer is imposed between the low pass filter and statistical voltmeter. When ANA (analyzer) is selected, the frequency meter reads the center frequency of the analyzer band pass filter.

3-35. The analyzer may be tuned over the range of 0.2 Hz to 20 kHz in five decade ranges. Ranges are incremented and decremented by the ANA RANGE switches. Analyzer bandwidth is ±5 percent of the center frequency (-3 dB). With ANA selected, the analyzer output signal is routed to the DEMOD OUT connector on the front panel for monitoring.

3-36. When the analyzer is in use, the TMA 3000 sets the low pass filter (LPF) bandwidth to the minimum that will pass all components in the selected analyzer range, subject to the limitation that the LPF bandwidths cannot exceed 1/5 of the carrier frequency. An attempt to use the analyzer at center frequencies greater than the LPF bandwidth will obtain erroneous measurements.

3-37. REMOTE MODE.

3-38. If the TMA 3000 is equipped with an IEEE 488 or an RS-232C interface, the Remote (REM) mode may be activated from the front panel. This transfers control from the front panel to a computer or controller on the bus.

3-39. All control commands are in the form of ASCII strings with mnemonics corresponding closely to the front panel labels. The external computer is able to specify reference frequency, filter bandwidth, mode, meter range, and analyzer center frequency directly rather than by UP/DOWN commands. In all other respects, remote operation is identical to manual operation.

3-40. OPERATION PROCEDURES FOR MEASUREMENT MODES.

3-41. Perform the following procedures to conduct the measurement modes.

a. Preliminary.

1. Place the TMA 3000 in operational readiness.

2. Place the recorder to be checked in normal operational readiness condition.

b. Procedure.

1. If desired, run TMA 3000 calibration check by pressing CAL (MODE) switch (figure 3-2).

2. Make interconnections between TMA 3000 and recorder in accordance with diagram in figure for specific measurement to be conducted (figures 3-3 through 3-7).

3. Set up TMA 3000 controls as listed in figure for selected measurement (figures 3-3 through 3-7).

4. Conduct selected measurement, reading meter in accordance with selected meter range and compare readings to manufacturer specifications for recorder.

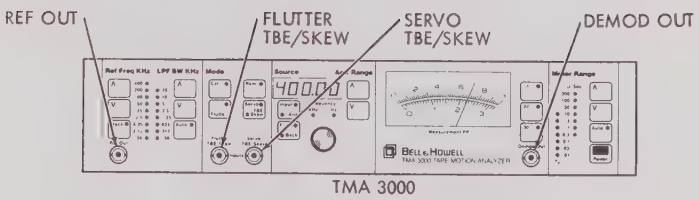
NOTE

System transients or discontinuities in the reference frequency signal may cause the analog meter to go off scale temporarily; pressing the lighted SIGMA switch will perform a brief reset of the measurement channel and clear this condition.

5. Conduct other desired measurements by repeating above steps 2 through 4.

6. Disconnect interconnections and return units to normal operational readiness.

CALIBRATION



Calibration mode requires no external connections, nor is it necessary to remove any existing connections.

MODE - FLUTTER, or TBE/SKEW

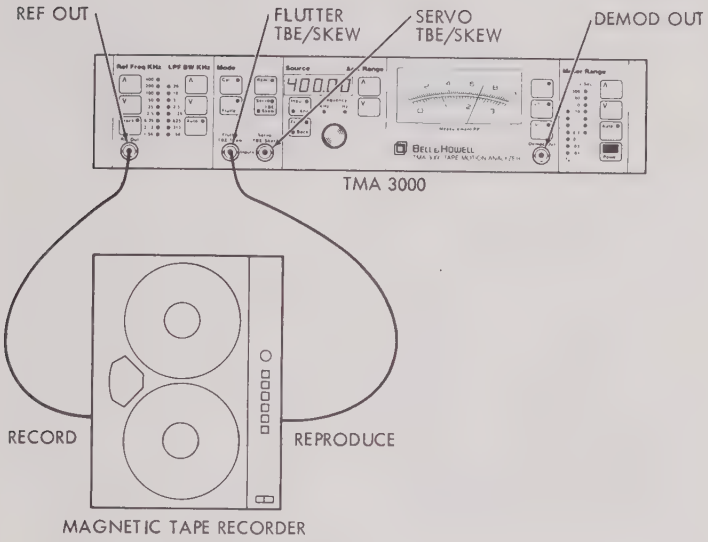
NOTE

In CAL, a full scale meter indication should be observed with a frequency reading of 25.04 to 25.09 kHz (FLUTTER) or 25.00 kHz (TBE/SKEW).

Other settings at any selection - The TMA 3000 automatically selects the correct conditions for calibration. When the calibration mode is exited, the previous settings are restored.

Figure 3-2. Operation in Calibration Mode

FLUTTER - SIMULTANEOUS RECORD/REPRODUCE



MODE - FLUTTER

REF FREQ - Suitable to tape speed (do not use TRACK)

LPF BW - As desired up to 1/5 REF FREQ (select AUTO for IRIG bandwidth corresponding to selected REF FREQ)

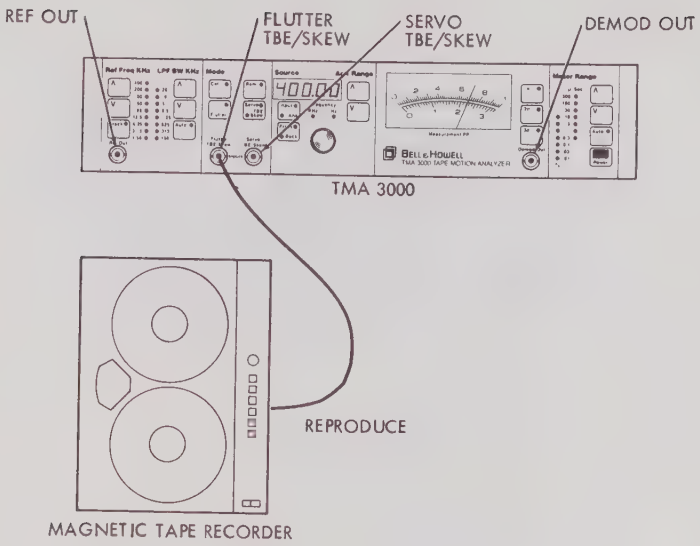
SOURCE - INPUT; FRONT (or REAR, as applicable)

σ - 2σ (normally used in flutter measurements)

METER RANGE - AUTO (or manually select a range to give a reading greater than ~20% of full scale)

Figure 3-3. Operation in Flutter Measurement Mode Using Simultaneous Record/Reproduce Condition

FLUTTER - RECORDED TAPE



MODE - FLUTTER

REF FREQ - Set to selected tape speed, or use TRACK (in TRACK, the TMA 3000 will automatically track speed changes of recorder and will find the input signal at either front or rear panel).

LPF BW - As desired up to 1/5 REF FREQ, or use AUTO [in AUTO, the IRIG recommended bandwidth corresponding to the REF FREQ (10% of REF FREQ, but not exceeding 10 KHz) is selected].

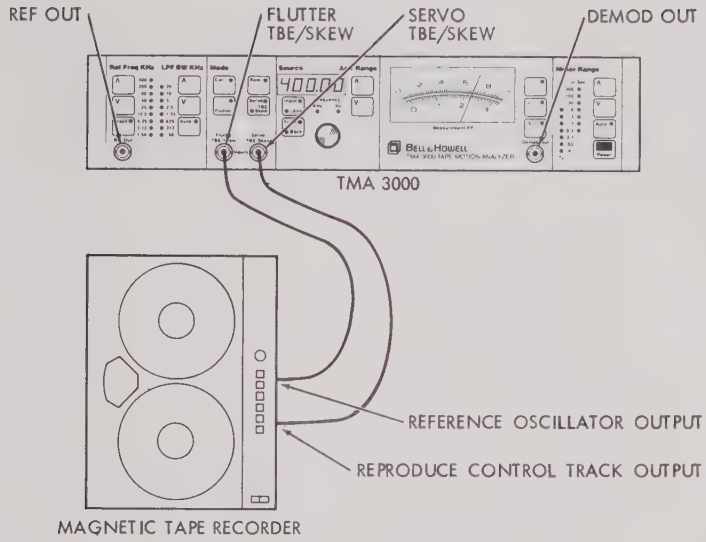
SOURCE - INPUT; FRONT (REAR if applicable)

σ - 2σ (1σ or 3σ optional)

METER RANGE - 0.01% pp to 10% pp as required, or AUTO

Figure 3-4. Operation in Flutter Measurement Mode Using Previously Recorded Tape

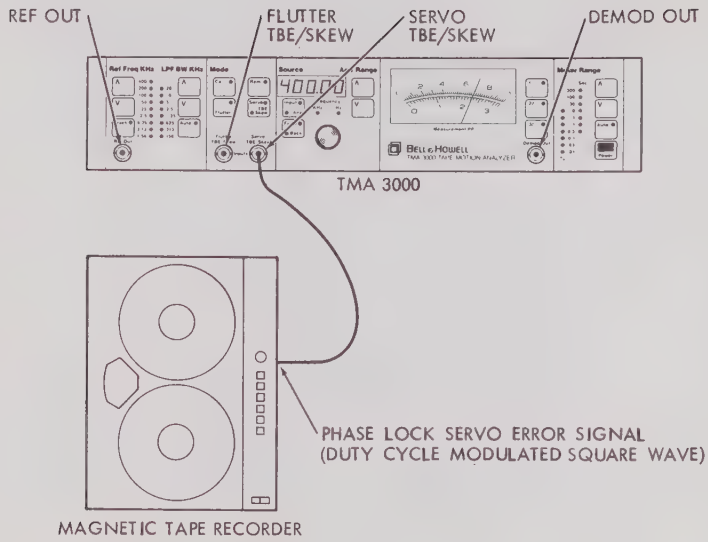
TBE - SERVO TAPE



MODE	-	TBE/SKEW
REF FREQ	-	Set to SERVO REFERENCE FREQUENCY, or TRACK (Note: The TMA 3000 measurement frequencies are the same as corresponding tape servo references.)
LPF BW	-	As desired up to 1/5 REF FREQ, or AUTO
SOURCE	-	INPUT; FRONT (REAR if applicable)
σ	-	2σ (1σ or 3σ optional)
METER RANGE	-	0.3 usec pp to 300 usec pp as required, or AUTO

Figure 3-5. Operation in Time Base Error (TBE) Measurement Mode Using Servo From Tape

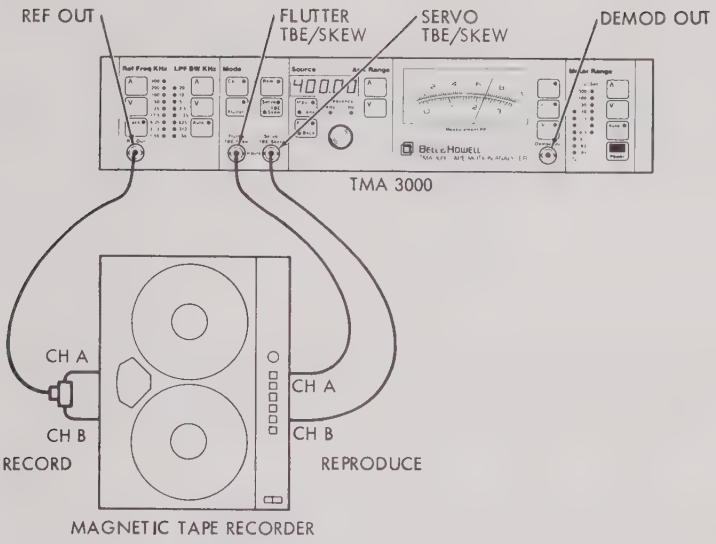
TBE - SERVO MODE



MODE	-	SERVO
REF FREQ	-	Set to SERVO REFERENCE FREQUENCY, or TRACK (Note: The TMA 3000 measurement frequencies are the same as corresponding tape servo references.)
LPF BW	-	As desired up to 1/5 REF FREQ, or AUTO
SOURCE	-	INPUT; FRONT (REAR if applicable)
σ	-	2σ (1σ or 3σ optional)
METER RANGE	-	0.3 usec pp to 300 usec pp as required, or AUTO

Figure 3-6. Operation in Time Base Error (TBE) Measurement Using Servo Mode

SKEW



MODE	-	TBE/SKEW
REF FREQ	-	Nominally SERVO REFERENCE FREQUENCY (other frequencies may be used as desired)
LPF BW	-	As desired up to 1/5 REF FREQ, or AUTO
SOURCE	-	INPUT; FRONT (REAR if applicable)
σ	-	2σ (1σ or 3σ optional)
METER RANGE	-	0.3 usec pp to 300 usec pp as required, or AUTO

Figure 3-7. Operation in Time Displacement Error (SKEW) Measurement Mode

SECTION IV

FUNCTIONAL DESCRIPTION

4-1. SCOPE OF SECTION.

4-2. This section provides a functional description of the TMA 3000 Tape Motion Analyzer. This description is presented modularly; that is, covering functions by module or circuit board. References are made to the module schematics provided in Section VII. For IEEE 488 and RS-232C functional descriptions, refer to the TMA programming for remote control discussed in Section VIII.

4-3. OVERALL UNIT CONTROL.

(Figure 4-1)

4-4. Some general comments concerning the functioning of the microprocessor, the TMA logic, and unit grounding are presented for understanding function control in the TMA 3000.

4-5. MICROPROCESSOR CONTROL. Virtually all TMA functions are under processor control. Conventional interface techniques would have the processor data bus distributed throughout the instrument, with each control location using a register to latch the appropriate data. While very fast and effective, this technique results in exposing the analog signals to the high frequency data bus noise. It also consumes a great deal of the circuit board, with numerous data and address lines winding through the circuitry.

4-6. To minimize unnecessary noise generation, the TMA 3000 uses a serial data bus technique. Control signals are transmitted serially on a single line to one or several serial in-parallel out shift registers which latch the data until the next command is issued. New commands are issued only on a change of operating condition, such as a mode or range change. In this way, the data paths are quiet during measurements. Each serial bus requires only a single data line and a clock line, significantly reducing the board space required for control functions. The TMA 3000 employs four data lines and seven clock lines, most of which spread out in tree fashion on the interconnect board.

4-7. The microprocessor uses a "real time clock" to pace its operation. A programmable timer generates interrupts at 160 msec intervals, initiating a series of operations. These operations include a scan of the front panel keyboard, reading the A/D converter which digitizes the meter reading, and issuing any commands required as a result of the scan or A/D reading. At the end of the interrupt service routine, the processor goes on hold, remaining inactive until the next real time interrupt or until an interrupt occurs from one of the communications interfaces. Operated in this mode, a processor duty cycle of less than 10 percent is experienced. When in hold, the processor bus is quiet, another way in which noise is minimized.

4-16. The 8085A X1 input is driven from a 4-MHz tap on the count-down chain, resulting in a nominal clock rate of 2 MHz. This rate is more than adequate for the relatively minimal tasks of the processor.

4-17. MEMORY. Provision has been made for up to three read only memories (ROMs) for program storage. Either 2048-byte 2716s or 4096-byte 2732s may be used, determined by three jumpers located around the address decoder U17. Initially, two 2716s are installed, but as requirements dictate, one 2732 could be substituted. Future program enhancements or special functions can draw upon the 3:1 ROM expansion available.

4-18. In a controller application such as this, random access memory (RAM) is used primarily for maintaining status data, I/O images, communications buffers, and the processor stack. These functions require modest amounts of memory. All requirements of the TMA 3000 are met by the 256 bytes of the 8155 multifunction chip.

4-19. INPUT/OUTPUT. Two I/O (input/output) chips have been includd, the 8155 (U18), and an 8255 (U12). Together, they have 46 lines of programmable I/O. These lines are distributed among four 20-pin ribbon cable connectors which interface the microprocessor board to the other TMA assemblies. The I/O functions include control of front panel displays, monitoring of the frequency meter, reading the A/D converter, monitoring front panel switches, and miscellaneous logic.

4-20. INTERRUPTS. The 8085A has three "restart" inputs which function as prioritized, vectored interrupts. In small systems, these restarts take the place of the interrupt controller and its more cumbersome and formal protocol. The restart inputs (RST 5.5, 6.5, and 7.5) are independently maskable in software.

4-21. REAL TIME CLOCK. During initialization, the 8155 counter/timer is set up to generate an interrupt at regular intervals of 160 milliseconds. This interrupt, RST 7.5, provides a "real time clock" which serves as the basic software pacing function.

4-22. In response to the real time interrupt, the processor scans the front panel switches, responds as required, performs any pending operations such as blinking lamps, monitors the A/D converter, and, when done, goes into the HALT mode. In this mode, the processor ceases to function, until it is activated by an interrupt. Depending on the current activity, the processor duty cycle is generally about 10 percent.

4-23. FAILURE DETECTOR. A special feature of the TMA microprocessor is the ability to detect when the processor has "bombed" or failed. Such a condition occurs on rare occasions, usually as a result of brief power outages or "glitches." Undetected, it can result in erroneous data and a non-responsive instrument.

4-24. On the occasion of an RST 7.5, the two-bit counter U19 is advanced to a count of 01 (binary). One of the first functions of the interrupt service routine is to reset the counter via the address decoder U22. If this reset does not occur before the next RST 7.5 (160 msec), the counter advances to the count of 10B, whereupon U21 (1, 2, 3) is enabled, initiating a processor reset (R16, C18 to the RES IN/ of U15).

4-25. The "bomb" detector reset is identical to a power-on reset and restores the TMA 3000 to its initial conditions. While this may interrupt a measurement sequence and cancel the REMote status, it is considered preferable to the indeterminate state of "hang up" that inevitably follows an undetected "bomb." The occurrence of mysterious resets may be an indication of an intermittent or incipient failure.

4-26. MISCELLANEOUS LOGIC. The address decoder U17 decodes three address lines to select one of the three ROMs or one of up to seven I/O devices. When configured for 2716 ROMs, the select lines (SEL 0 to SEL 7) define eight contiguous memory blocks of 2048 bytes each or eight I/O blocks of 8 addresses each. In the 2732 mode, the memory blocks are 4096 bytes each and the I/O spaces constitute 16 addresses. It is required that memory and address assignments be made so that only one assignment falls within any address space.

4-27. The address latch U23 latches the low order byte of the address to be accessed during the first state of a processor cycle. The address latch implements the hold function required for the 8085A bus multiplexing scheme.

4-28. CALIBRATION GENERATOR. The flutter and time base signals (processed by the TMA 3000) require but have no ready source of simulation inputs for test and calibration purposes. Flutter test signals may be obtained from an FM modulator, but accurate calibration involves either expensive synthesizers or laborious lab setups. Therefore, an inherently calibrated signal source has been included within the TMA 3000 to ensure that calibration may be verified at any time and may be set precisely during periodic maintenance.

4-29. Integrated circuits U1 through U7 implement the calibration generator by alternately selecting different count-down ratios in counters U6 and U7 for the two states of the modulation frequency FMOD. The result is a signal whose frequency alternates between two sub-harmonics of the 8-MHz clock at the 195 Hz rate of FMOD. Since all frequencies are derived from the crystal oscillator by direct digital synthesis, the frequencies are extremely accurate ($\pm$0.01 percent) and their ratios are absolute. Thus, the percentage of modulation ($\overline{f}$lutter) is absolutely accurate.

4-30. The TBE/SKEW signals are generated in a similar manner, deriving all timing from the crystal controlled oscillator. The resultant skew calibration signals are two waveforms whose net time displacement alternates by 80 counts of the 8-MHz clock. Thus, the TBE/SKEW calibration is accurate to the $\pm$0.01 percent tolerance of the crystal oscillator.

4-31. EXPANSION CONNECTOR. A 34-pin ribbon cable connector, J2, provides expansion capability and serves as the communications interface for the microprocessor board. The RS-232C or IEEE 488 interface boards plug directly into this connector and derive both power and data from it. By providing the three RST lines and five of the seven address decode lines, the expansion connector is able to support several external peripherals, including the communications interface chips, additional I/O, or even an interrupt handler should additional interrupts be necessary.

4-32. TEST CONNECTOR. The test connector, J7, is used in testing and diagnosis of boards in production and provides the capability of remotely activating the on-board address, data, and control lines. It has no function in TMA operation or field testing.

4-33. INPUT CHANNEL CONDITIONER.

(Figure 4-2; Schematic, Figure 7-3)

4-34. Two identical circuit boards are used to condition signals applied to the FLUTTER-TBE/SKEW and SERVO-TBE/SKEW inputs. Conditioning includes automatic leveling, band-pass filtering, limiting, and level sensing. These functions are described in the following paragraphs and are illustrated in the block diagram of figure 4-2.

4-35. In order to minimize the effects of noise on the flutter or skew measurements, the input signal must have the maximum signal-to-noise ratio possible. Generally, this requires that any out-of-band signal components be filtered out and that the input signal level be adjusted to achieve the full dynamic range of the filters and limiters. An amplifier at the very input to the board is gain controlled to achieve a constant signal level at the output of the filters. The degree of amplification required is sensed as an indication of signal level. If the amplifier is unable to achieve adequate gain, the signal is declared too small. After filtering, the signal is limited and converted to the 12V pp level of the TMA CMOS logic.

4-36. AUTOMATIC GAIN CONTROL. The key element of the automatic gain control (AGC) is the photo-modulator, VTLI. Current through the LED section of VTLI results in infrared radiation on the two cadmium-selenide photoresistors, causing their electrical conductance to increase in approximate proportion to the LED current. The two resistor sections, RT1 and RT2, are employed in the feedback and feedforward, respectively, paths of operational amplifier U1. As LED current is increased, input attenuation is reduced and amplifier gain is increased. The combination of input attenuation and gain variation give the TMA 3000 a wide dynamic range and an ability to handle large signal levels.

4-37. Two gain control feedback paths are provided. The normal path, with Q4 as a level sensing element, maintains the band-pass filter output level at approximately 3V pp. If the input signal is not within the filter frequency range, or if a large out-of-band signal component is present, Q5 senses that the level at U1 output is greater than about 4V pp and assumes control of the AGC. This serves to prevent generation of false carrier signals due to nonlinear effects in the input or filter stages.

4-38. Operational amplifier U2, (2, 3, 1) senses the voltage at Q4 collector, the "normal" AGC voltage. If the dc level at Q4 collector becomes more negative than about -8V (exact level will vary among units), it may be assumed that the input signal level is too small to be usable, or that AGC control is vested in Q5. In any case, the signal is either insufficient, out-of-band, or contains large out-of-band components rendering the signal unusable. Comparator U2 (5, 6, 7), via Q6, Q8, and Q7 cuts off the limiter and causes the PC output to go true, signifying

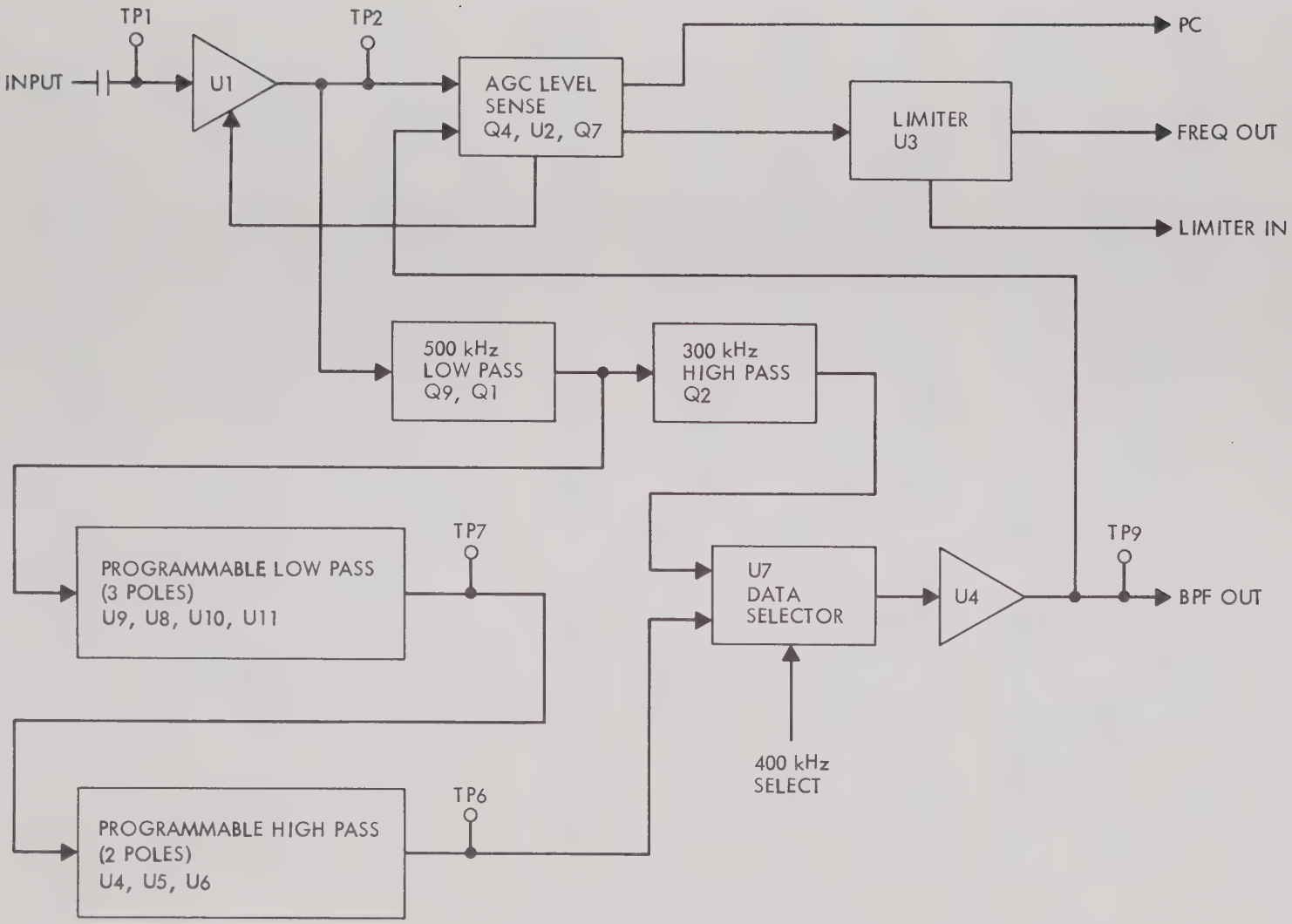


Figure 4-2. Input Channel Conditioner Block Diagram

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D271-B2

this to the microprocessor. The AMP DIS input on pin 9 makes use of this process by allowing Q5 to be turned on from the control logic, which in turn causes the limiter to be disabled.

4-39. BAND-PASS FILTERS. The automatic gain controlled signal from U1 goes to the low-pass active filter Q9 and Q1 and associated components. This filter removes signal components beyond about 500 kHz. An emitter-follower implementation of the Sallen-Key configuration has been used to handle this relatively high frequency application. From the 500-kHz section, the signal splits, one path leading to a similar emitter-follower 300-kHz high-pass section, and the other to the programmable state-variable filters (U8-U11 are low-pass, and U4, U5, and U6 are high-pass). In the 400-kHz reference frequency setting, the signal path through Q2 is selected (U7), providing the 300-kHz to 500-kHz bandpass required. If lower frequencies are selected, the state-variable path is picked.

4-40. Analog data selectors are used to select one of eight precision resistors for each filter pole. In the low-pass filter, U9 determines the single pole section, and U10 and U11 determine the two-pole cutoff. Combined, these sections characterize a three-pole Chebyshev low-pass filter whose cutoff is approximately 50 percent higher than the nominal reference frequency.

4-41. A two-pole state-variable section U4, U5, and U6 constitutes the high-pass portion of the input filter. The high pass is tuned to about 60 percent nominal.

4-42. The filter bandpass is set wide to accommodate a range of input frequencies of -10 percent to +20 percent. This will allow either 400-kHz or 432-kHz based references to be used, and will accept some tape speed variation without loss of accuracy.

4-43. Separate control of low-pass and high-pass cutoffs allows the filter to be opened up to implement signal acquisition in the search phase of the TRACK mode.

4-44. The band-pass output (U4,14) goes to the edge connector and then to the interconnect board from which it is routed to the rear panel BPF output.

4-45. LIMITER. Integrated circuit U3 forms a dual section emitter-coupled limiter, which amplifies the filtered input to the point that only the zero crossings remain. The limiter output is a square wave at the CMOS logic level of -6V to +6V, and interfaces the input board to the following demodulator logic.

4-46. Transistor Q8, when saturated, cuts off the current in the two emitter-coupled amplifier sections when there is no input signal present or when the input channel conditioner is disabled. This prevents noise from an inactive channel from coupling into the sensitive demodulator circuitry.

4-47. D-MOD BOARD.

(Schematic, Figure 7-5)

4-48. The D-MOD board mounts on the underside of the microprocessor tray. A sheetmetal shield protects it from physical damage as well as from electrical

radiation. Two distinct circuits are on the D-MOD board: The flutter demodulator and the time-base error demodulator. These circuits are described below.

4-49. FLUTTER DEMODULATOR. The flutter demodulator is a low noise, precisely calibrated frequency discriminator. It uses the principle of "pulse averaging" to generate a voltage proportional to the instantaneous frequency at its input. In a pulse averaging configuration, one precisely measured pulse of charge is delivered to an integrating filter for each zero crossing of the input signal. When a steady current is subtracted from the series of pulses, the result is a net current proportional to the difference between the input frequency and a constant frequency, the "center frequency." This current is converted to a voltage in a summing amplifier and then low-pass filtered to remove any frequency components above the band of interest. On the D-MOD board, the discriminator and first two sections of a six-pole low-pass filter appear.

4-50. An emitter-coupled discriminator is used, where transistor array U8 forms the active element with U9 selecting one of seven timing capacitors C12-C16 and C22-C25 according to the selected reference (center) frequency. Timing current is determined by current sources of U4 and their low noise voltage reference U3. An offset current is developed in U7 (5, 6, 7) slaved to the sources of U4 (3, 4, 5 in particular). Each time the input signal reverses, the direction of current flow in the timing capacitor is reversed and the capacitor voltage swings by an amount equal to twice the amplitude of the square wave on R32 and R28 less the bias on R29. When such a reversal occurs, an amount of charge equal to C*V (timing cap and voltage swing) does NOT get conducted out of the summing junction of operational amplifier U6 (2, 3, 1). When the input frequency is such that the current into the summing junction is zero, balance occurs and the output is zero.

4-51. Depending on the selected low-pass filter bandwidth, U2 grounds the lower end of one of the capacitors C1-C6, C9-C11. The selected capacitor, in combination with resistor R21, forms the first filter pole. Potentiometer R19 sets flutter demodulator gain.

4-52. A common problem with pulse averaging circuits is that their "gain" is an inverse function of the incoming frequency, and frequencies displaced from the nominal center experience gain errors. This would affect flutter demodulator accuracy significantly were it not for the automatic frequency circuit of U6 (12, 13, 14). Any input that causes the average voltage at the FDMOD output (U6, pin 1) to move from zero will cause integrator U6 to charge in the opposite direction. This, in turn, will adjust the bias voltage on R29 and shift the "center frequency" of the discriminator to reduce the offset to zero. In this way, the demodulator is always operated at its nominal center, and gain remains constant. A second benefit of the AFC is that no DC component exists in the demodulated signal, eliminating transients during range changes and speeding settling. The AFC has a frequency tracking range of about +20 percent, -10 percent. An offset has been built into the range to accommodate carriers of 400-kHz down or 432-kHz down. This makes the TMA 3000 compatible with tapes recorded for old style flutter meters.

4-53. Comparator U1 senses the AFC voltage, indicating an out-of-range error if the AFC is unable to track the input.

4-54. TIME BASE ERROR D-MOD. The TBE, skew, and servo signals are demodulated in the TBE section of the D-MOD board. The "ramp and sample" technique is used to convert the time displacement between the two input signals of the TBE demodulator to an equivalent voltage. As with the flutter demodulator, the first filter pole is located on-board.

4-55. Two TBE inputs come from the input channel conditioners. These signals, at TMA digital levels (-6V to +6V), are combined in U18 and low-pass filtered by U20 (2, 3, 1). The dc level of U20 output indicates the relative phase of -TBE signal with respect to +TBE signal. The second section of U20 functions as a comparator to gate either -TBE or its inversion to the demodulator. Both +TBE and -TBE signals are NOT inversions, but are the outputs of two separate channels. This phase preselect ensures that the demodulator will have the greatest possible dynamic range, regardless of the static time displacement between the two inputs.

4-56. The TBE inputs trigger narrow pulses in the dual one-shot, U13. The pulse triggered by +TBE initiates a ramp and the pulse triggered by -TBE simultaneously terminates the ramp and samples its voltage. After the sample pulse, capacitor C35 is charged to the final ramp level. Since the ramp rate is constant and calibrated, the voltage is proportional to the time interval between +TBE and -TBE. At each successive sample, the capacitor voltage is updated so that its ac component represents the variation of pulse interval. This, of course, is the time base error.

4-57. TBE calibration is derived from the ramp rate, which is determined by the capacitance of C38 and C39 (higher reference frequencies) or C37-C39 and C51 (lower frequencies) and the current source formed by Q13 and the selected resistor of RN4. An overall calibration adjustment is provided by the potentiometer R70. Another calibration point is necessary to reconcile the binary relationship of ramp rates and the 3.16:1 ratio of TBE meter scales. This is accomplished by the programmable attenuator formed by R66, RN2, and the analog switches U14 and U19. Range gains are programmed by the microprocessor writing an attenuation control byte into the two sections of register U17.

4-58. Data selector U10 (3, 4, 5) selects either the buffered TBE output (U15, pin 8) or the demodulated flutter FDMOD depending on whether TBE or flutter mode is active. A second low-pass filter pole is formed by one of the resistors of RN1 and the shunt capacitance of C31 and C47 (flutter) or C31, C47, C32, and C48 (TBE). The filter output is buffered by U15,(3, 2, 1) and then goes to the interconnect board via the cable to J1.

4-59. Logic control on the D-MOD board comes from the processor via shift registers U21 (reference frequency selection and TBE control) and U17 (TBE attenuator). Serial data line DATA1 and clock CK1 are used.

4-60. INTERCONNECT BOARD.

4-61. The interconnect, or mother board, is covered in a five-sheet schematic (figure 7-6). Since the sheets are organized by function, the circuits will be described sheet by sheet.

4-62. SHEET 1. The computer interface, D-MOD board interface, power supply connector, and clock and data decode circuits are illustrated on this sheet. Translation of serial data and clocks from the TTL input levels to the CMOS -6V to +6V is accomplished by operational amplifiers used as comparators. High-speed FET operational amplifiers U23 (TL084) and U56 (LF356) are used for clocks and data, respectively, and an LM358 translates the REMOTE status and VMRST (voltmeter reset) signals. A digital multiplexer, U14, and an analog multiplexer, U19, steer clock and data information to their destinations.

4-63. Multiplexer (mux) U7 selects MFREQ, the input to the frequency meter, and U10 is one of the data shift registers that latch control data.

4-64. SHEET 2. The second sheet of the schematic shows the four FET source follower input buffers (Q3-Q6), and U4, the data selector which routes the input signals to the input signal conditioners. The calibration signals coming from the microprocessor board via J3 and buffered in Q1 and Q2, are introduced into U4. This ensures that calibration is introduced early in the circuitry and covers as much of the TMA 3000 as possible. Input channel analog outputs from pins 17 go to the rear panel outputs from terminals E9 and E11. The digital output of the flutter channel (CH 1 SQ) goes on to counter U15 and selector U9, where, for reference frequencies greater than 100-kHz, it is counted down to 100-kHz. At 100-kHz and below, the digital signal is not counted down, but goes directly to the D-MOD board.

4-65. Shift registers U5 and U8 latch control data for input selection, reference frequency, and input bandpass filter selection. Data selector U20 steers the digital signals (CH 1 SQ and CH 2 SQ) to the two TBE channels.

4-66. SHEET 3. The D-MOD output (D-MOD OUT) contains artifacts of the reference frequency carrier as well as frequency components that may be out of the range of interest for a given analysis. In the circuit section of sheet 3, two filter sections remove the unwanted components and provide gain scaling amplification to implement the selected meter range.

4-67. Two complete state-variable filter sections are shown. The upper section comprises U28, U36, and U37, and the lower U30, U38, and U39. The analog multiplexers select one of the precision elements of the resistor networks RN1 and RN2. Only one resistor of each network is picked at a time, and its value determines the resultant filter bandwidth. Different damping characteristics are given by the feedback networks R80/R65 and R90/R89. When the four poles of these two filter sections are combined with the two poles located on the D-MOD board, a six-pole low-pass filter results. The filter characteristic is best described as a "5-1/2-pole" Butterworth, for it is synthesized from a 5-pole maximally flat filter with an additional pole at twice cutoff frequency to reduce overshoot.

4-68. Following each filter section, a programmable gain amplifier (U28, pins 3, 2, 1 and U29 and U30, pins 3, 2, 1 and U31) amplifies the filtered signal according to the selected meter range. Depending on which tap of the feedback attenuator is selected, each amplifier can have a gain of 0dB, +10dB, +20dB, or +30dB. Gain and filter bandwidth selections are performed by the microprocessor via the shift register U33.

4-69. Two analog switches (U26 pins 10, 11, 12 and pins 9, 8, 6) ground the signal at the inputs to the gain stages when the VMRST signal is asserted. This reduces the signal level to zero and dissipates any charge that might have accumulated on the high-pass capacitors from an out-of-range signal or from a gain or filter selection transient. It is this feature that allows rapid recovery from overloads or function changes. VMRST is asserted by the processor whenever a range or function change is initiated or when a front panel button is pressed.

4-70. The output of the second filter section goes to the analyzer (see sheet 4), where, if ANA is selected, it is bandpass filtered. In the ANA mode, ANA INH is false, selecting the analyzer output as input to the second gain amplifier. Otherwise, the low-pass filter output is fed to the second gain stage. The second gain stage output is the input to the statistical voltmeter (STVM INPUT). (See the description for sheet 5.)

4-71. SHEET 4. A high Q bandpass filter, tunable over a broad range, aids in performing spectral analysis of flutter or TBE signals. Sheet 4 contains all of the analyzer circuitry.

4-72. The analyzer is a state-variable bandpass filter whose Q is set at 10. Frequency tuning is accomplished by variable duty cycle modulation of the effective value of a precision resistor. Using variable duty cycle, accurate frequency setting is possible over a range of several decades.

4-73. Operational amplifier U17 and analog switches U11 and U21 comprise the basic state variable filter. When the logic signal SAMP is true (and its complement is false), switch section U11 and U21 pins 3, 4, 5 are closed, conducting-signal current into the respective summing junctions of the two state-variable integrators. When SAMP goes false, the switch sections open and no current is allowed to flow. If the switches are opened and closed at a rapid rate (50X the desired bandpass frequency), the affect is as if the conductance of the resistors R41 and R36 were varied proportionally to the duty cycle of the signal SAMP. This, in turn, tunes the filter center frequency.

4-74. Duty cycle control is achieved by triggering a fixed pulse width one-shot (U41, pins 4, 6, 7) from a digital signal whose (high) frequency is proportional to the desired center frequency. Frequency control is established by feeding a dc voltage from the front panel frequency potentiometer into a voltage-to-frequency converter in which feedback comes from a discriminator one-shot (U41 pins 12, 10). Voltage controlled oscillator U27 generates a frequency in the range of 100 kHz to 1 MHz. This frequency is then counted down in counter U32 and the correct divider selected by U34. In the REMOTE mode, a digital/analog converter (U18), loaded from the controller through the microprocessor, replaces the front panel potentiometer.

4-75. Two frequency ranges are employed to cover the five decades of the analyzer filter. On the 200-2 kHz and 2-20 kHz ranges, switches U11 (pins 1, 2, 13) and U21 (pins 10, 11, 12) are open, making the effective integrator capacitors 1000 pF. On lower ranges, these switches are closed, increasing the capacitance to 0.1 uF. Separate Q controls (R167, R168) are provided to adjust the gains on the two ranges.

4-76. Because the duty cycle modulated filter output is a sampled waveform, it contains some frequency artifacts which might interfere with subsequent analysis. Therefore, an analog low-pass "post filter" is used to clean up the waveform. The post filter formed by U17 (pins 10, 9, 8) and U22 and associated components cuts off approximately 1.5 X the highest frequency of each range.

4-77. SHEET 5. Statistical levels are defined as those levels that the signal is "less than" for a specified percentage of the time. For example, the signal is less than the 2 sigma level 95 percent of the time. The statistical voltmeter makes this measurement by using feedback to generate one voltage which is more positive than the input 97.5 percent of the time and another which is more negative 97.5 percent of the time. The sum (magnitude) of these two voltages is equal to the 2 sigma pp level.

4-78. The STVM INPUT signal is first amplified in U47 (pins 5, 6, 7) to minimize the effects of any offsets and then applied to the + inputs of three comparators of U46. According to the selected sigma level, the output of buffer amplifier U51 (pins 5, 6, 7) is applied to the - input of one of these comparators. The inputs of unselected comparators are held low, so they do not affect the measurement. When the input signal is more negative than the input of the comparator (and thus more negative than the voltage on capacitor C45), the comparator output goes negative, causing a measured current to flow through its output resistor (R104, R106, or R108), through Q8, and out of C45. An equilibrium is achieved when the current drawn out of C45 equals the constant current that flows into C45 through R111 and Q9. This equilibrium obtains when the duty cycle of the comparator is equal to the ratio of the comparator output resistor to R111. For 2 sigma, the ratio is 2.5 percent, implying that the input is more negative than the voltage on C45 exactly 2.5 percent of the time. The input signal is inverted in U51 (pins 9, 10, 8) and processed in an indentical circuit, charging C47 in the same way. The voltage on C45 represents negative peaks; the voltage on C47, positive peaks. Summing the two capacitor voltages in U51 (pins 2, 3, 1) obtains the pp level.

4-79. By virtue of the calibration adjustments on the D-MOD board, the dc voltage at STVM OUT is a calibrated (4V full scale) level. This voltage is fed to the analog selector U44 and then to the A/D converter U43 where it may be measured by the microprocessor. A resistive attenuator (R146, R172, R147) matches the impedance of the meter and provides the opportunity to adjust meter calibration.

4-80. Analog data selector U44 has inputs from each of the power supplies as well as from the statistical voltmeter. The microprocessor uses these inputs to measure the power supplies on power up, and will not allow the TMA 3000 to operate until the inputs are within 10 percent of nominal.

4-81. Also on sheet 5 is the reference frequency generator (U52-U55) and reference output amplifier (Q14, Q15). Variable resistor R156 provides an intermal adjustment of the reference output level.

4-82. FRONT PANEL DISPLAY.

4-83. The front panel display board contains control logic and drivers for the LED indicators as well as the frequency meter integrated circuit and its display. This board appears in the two-sheet schematic of figure 7-2.

4-84. SHEET 1 (Figure 7-2). All front panel display data other than the frequency display is transmitted to the display board on a single data line clocked by CKO. A total of four bytes is shifted through registers U2, U3, U8, and U12. These bytes select the LEDs to be lighted for each group of indicators and also pick the appropriate frequency meter decimal point. Individual LEDs, such as AUTO FILTER, TRACK, etc., are driven by single buffers U7, U9, and U10. Multiple LED arrays such as the REF FREQ or FILTER BW groups use decoder/driver chips (74LS145) U1, U11, and U13 or 74LS139 decoder U4 to select one of a number of devices to be driven.

4-85. Darlington power transistors Q5 and Q2 are turned "off" during the time data is being shifted in to prevent extraneous flickering of the display. The disable signal LED DIS is generated by the processor and remains true during transfer.

4-86. SHEET 2 (Figure 7-2). An Intersil ICM 7226 single chip frequency counter handles all counter and display driving functions. An "external" reference frequency input from the microprocessor board (1 MHz), the frequency to be measured (FREQ IN), and a HOLD signal are the only inputs to the counter. Five LED digits (D1-D5) are multiplexed and driven from the 7226. Analog multiplexer U5 gates one of the digit select lines (D1-D5) to feed back to the counter to light the appropriate decimal point.

4-87. Provision has been made for a buzzer to make audible key-clicks to supplement the tactile feedback of the front panel switches. This circuitry is not presently being used and is shown for reference only.

4-88. POWER SUPPLY.

4-89. The TMA 3000 power supply is located on the right side panel. Figure 7-4 shows the power supply circuit. Part of the power supply is the series pass transistor, Q1, located on the rear panel. The socket for Q1 is hard wired to the power supply board, but Q1 itself may be removed without unsoldering any connections.

4-90. Also located on the rear panel is the power transformer, T1. This location allows for excellent heat transfer and reduces the protrusion of the transformer into the interior of the enclosure. Dual primaries on the transformer provide for either 115V or 230V mains operation. Switch SW2 on the rear panel allows simple selection of mains voltage. The transformer has been designed for operation at nominal line frequencies from 50 to 400 Hz.

4-91. The two transformer secondaries are connected to the power supply board via a cable which plugs onto connector J1. The higher voltage winding (pins 5, 6, 7 on T1) is rectified in a full-wave center-tapped configuration (CR5-CR8, C2, C3) to yield raw dc voltages of ±18V nominal. The ±18V supplies are used for both ±12V and ±6V regulated supplies. The remaining secondary (pins 8, 9) is rectified in bridge CR1-CR4, C3 to a raw dc of approximately 9V used for the +5V regulated supply.

4-92. +5V REGULATOR. Integrated circuit U1, an LM723 regulator, controls the +5V series pass device Q1. U1 contains a stable voltage reference, an operational amplifier, and the specialized circuitry which implements foldback current limiting. Resistors R2-R4 set the foldback limit to about 0.5 ampere.

4-93. The +7.15V (nominal) reference of U1 is divided down in attenuator R5, R8, and R7. Potentiometer R8 is adjusted for exactly +5V at its wiper, which, in turn, fixes the +5V supply at that same level. The level at R8 wiper also serves as a reference for the other supplies.

4-94. Because of the sensitive microprocessor components on the +5V supply, a "crowbar" over-voltage protection circuit has been incorporated. If the level at TP1 exceeds about 6.2V, sufficient current flows through zener diode CR15 to trigger the thyristor, SCR1. The SCR, when turned "on," appears as a near short circuit, loading the +5V supply beyond its capacity, and pulling its level to about 1.2V dc. If the initial over-voltage condition was not the result of a faulty series pass circuit, the foldback circuit will drop the short circuit current to a safe level of 0.5 to 1.0 ampere. If, on the other hand, a failure occurred in Q1 or U1 to prevent foldback, the SCR will conduct as much current as can be supplied until either Q1 or R1 opens or the line fuse opens. The over-voltage trip can be reset only by turning power "off" and then back "on" again (assuming the fault condition has been cleared). Rectifier CR20 protects the +5V supply and any circuits to which it is connected in the event a reverse voltage is applied to its output.

4-95. +12V REGULATOR. U2 (3, 2, 1) and voltage regulator VR1 form a basic voltage regulator with the operational amplifier serving to compare the output level as attenuated by resistors R10 and R9 to the +5V reference from the wiper of R8, and VR1 being utilized as a series pass transistor. In this way, the +12V supply tracks the +5V supply with an accuracy determined only by the 1 percent resistors in the divider, and the current limiting and thermal protection of the three-terminal regulator may be obtained. Zener diode CR14 serves to limit the maximum output level to about +13.2V in the event of a failure in U2 or in the reference circuits.

4-96. Rectifier CR19 protects the +12V circuit from accidental voltage reversals, and capacitor C12 acts to maintain the supply output impedance low at high frequencies where the feedback circuit is running out of gain.

4-97. +6V REGULATOR. Operational amplifier U2 (9, 10, 8) and voltage regulator VR2 are identical to the +12V circuit except that resistive divider (R17 and R18) is set for +6V, and a slightly smaller zener (CR12) is used.

4-98. -12V REGULATOR. The -12V circuit is similar to its positive counterpart except that the +12V supply is used as its reference, so that the negative supply tracks the positive. Having "equal but opposite" supplies is useful in many analog circuits.

4-99. -6V REGULATOR. The -6V circuit is slaved to the +6V supply in a similar manner to the -12V supply. Due to slight internal differences in the MC7805 and MC7905 three-terminal regulators, compensation capacitors C7 and C8 are necessary in the negative circuits.

4-100. GROUNDING. The +5V, ±6V, and ±12V grounds are all commanded on the power supply board at connector J2. This is the only location that the digital (+5V) and analog (±6V and ±12V) supplies are connected.

4-101. HEAT MANAGEMENT. The series pass three-terminal regulators are mounted to an aluminum block which conducts heat to the enclosure side panel. High thermal conductivity insulator pads are used to provide electrical isolation. Connectors on the power supply board permit removal and replacement of the devices with only a screwdriver.

4-102. The MJE800 +5V series pass transistor is mounted to the TMA 3000 rear panel to ensure that it has the maximum possible heat transfer. As with the three-terminal devices, a high thermal conductivity insulator is used. To promote easy replacement, a cable-mounted socket is used.

SECTION V

MAINTENANCE INSTRUCTIONS

5-1. SCOPE OF SECTION.

5-2. This section contains information and instructions for maintaining the TMA 3000 Tape Motion Analyzer. Included are instructions for adjustment and calibration, troubleshooting, and repair. No special tools or equipment are required to perform these procedures.

5-3. REFERENCE DESIGNATORS.

5-4. For ease of identifying circuit boards of the TMA 3000 in this section, the following arbitrary alphanumeric designators are assigned:

Board Assy	Designator	B&H Part No.
3024 Interconnect	A1	552100-6000
3020 Input Channel 1	A2	552100-9000
3020 Input Channel 2	A3	552100-9000
3004 Microprocessor	A4	552100-7000
3041 D-MOD	A5	552100-8000
3008 IEEE 488	A6	552108
3012 RS-232C	A7	552109
3037 Power Supply	A8	552100-4100
3016 Display	A9	552100-2100

5-5. INSTRUMENTATION TECHNIQUE.

5-6. The following basic requirements for maintenance measurements should be adhered to in the calibration of the TMA 3000.

a. Monitor test points with calibrated low capacitance oscilloscope probes. Always use probe ground clips with short (6 inches or less) leads.

b. Monitor frequencies by connecting counter to oscilloscope outputs, using low capacitance probe as required.

c. Proper termination of signal sources is essential to waveform purity and measurement accuracy.

d. Allow 20 minutes for the TMA 3000 and all calibration equipment to warm up.

5-7. ADJUSTMENT AND CALIBRATION.

5-8. INSTRUMENT ACCESS. Performance verification, metering, and adjustment of the TMA 3000 require electrical access to test points and connectors, and physical access to adjustments. Such access is provided by performing the following steps with the ac power disconnected.

a. Procedure.

1. Remove four Phillips-head screws securing top cover. (Do not loosen or remove nickel-plated, oval-head screws that secure front-panel hold-down rail.) Hinge-mounted microprocessor board (A4) is exposed.

2. Remove two 8-32 screws that secure aluminum tray of microprocessor A4 board.

3. Lift front edge of microprocessor A4 board, which hinges from back, until A4 board is tilted back far enough for attached phenolic support leg to rest on top of power transformer to support weight of A4 board. (Ensure that phenolic leg goes into prop position to avoid physical contact with components and possible damage.)

5-9. MAINTENANCE CHECKS AND ADJUSTMENTS. Table 5-1 is a maintenance reference, which is a list of maintenane adjustments with cross references to the paragraph for the respective adjustment procedure. Locations of test points and adjustments are illustrated in figure 5-1. It is recommended that the following checks and adjustments be performed in the sequence presented.

5-10. Initial Performance Check. A rapid performance check may be made by performing the abbreviated following test procedure. The results of these tests do not certify calibration, but are an indication of whether the circuits are functional or in need of repair.

a. Procedure.

1. Plug power cord of the TMA 3000 into power receptacle and press POWER switch to on. Observe that one or more panel indicators light.

2. Press MODE pushbuttons FLUTTER and CAL to selected mode.

NOTE

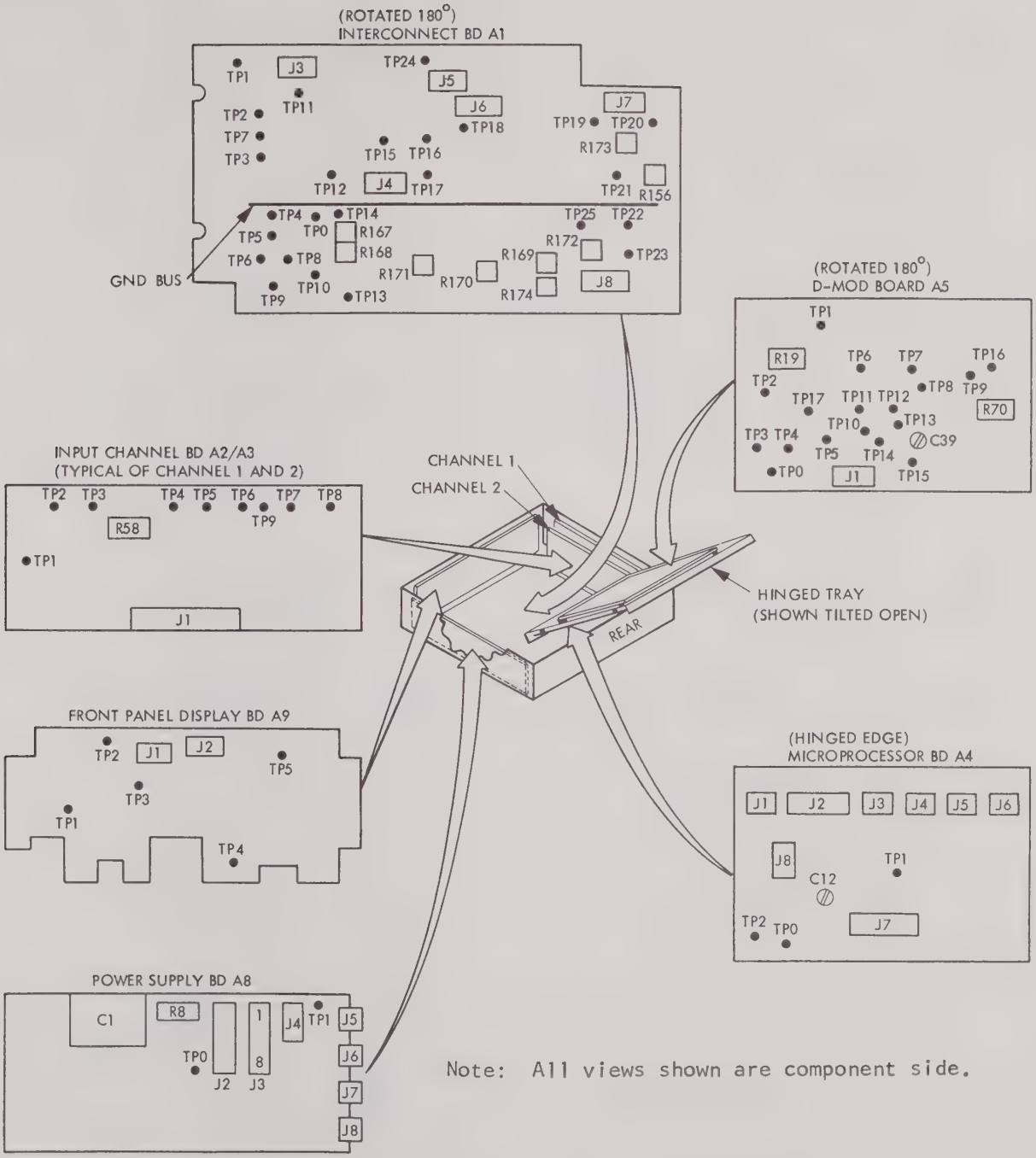
Placing TMA 3000 in CAL mode internally connects precision calibration signal to input of flutter channel, which allows operator to verify operation through principal flutter-measuring path. In CAL mode, TMA 3000 selects 25 kHz REF FREQ, 2.5 KHz LPF BW, 1 sigma, and 10% meter range.

3. Verify that measurement pp meter reads exactly 10%.

4. Verify that digital FREQUENCY meter displays readout of approximately 25.08 KHZ $\pm$4 Hz.

NOTE

If readings of steps 3 and 4 are as specified, then majority of TMA 3000 functions are operational.



Note: All views shown are component side.

Figure 5-1. Adjustments and Test Point Locations, TMA 3000

PARA NO.	ADJUSTMENT	REF DES OF ADJUSTMENT	ADJUSTMENT SPECIFICATION
5-11	Adjust regulated +5 volt power supply	A8 R8	5.000 ±0.005 Vdc at A8 J3-1
5-12	Adjust microprocessor or clock frequency	A4 C12	8.000000 MHz ±10 Hz at A4 TP2
5-13	Adjust reference frequency output level	A1 R156	3 Vpp ±5% at REF OUT connector
5-15	Adjust meter zero (deenergized)	Zero adj at back of meter	Calibration zero as viewed from face
5-17	Adjust meter gain	A1 R172	Adjust for full scale as read
5-19	Adjust voltage reference	A1 R173	2.500 Vdc readout at A1 TP20
5-20	Adjust TBE/Skew gain (time scale)	A5 R70	Full scale (10 ms) read on meter face
5-21	Adjust flutter gain (percent)	A5 R19	Exactly 10% read on meter
5-23	Adjust analyzer limits	A1 R174	1.95 KHz on frequency meter
		A1 R170	20.5 KHz on frequency meter
5-24	Adjust analyzer	A1 R171	Peak meter reading
		A1 R168	10% meter reading
		A1 R169	205.0 Hz readout on frequency meter
5-25	Adjust input range sensitivity	A2 R58	For flashing 10% range LED
		A3 R58	For flashing 10% range LED

Table 5-1. List of Maintenance Adjustments

5. Press CAL pushbutton to deselect calibration mode.

6. Press FLUTTER pushbutton to deselect flutter mode.

7. Press MODE pushbuttons TBE/SKEW and CAL to selected mode (TMA 3000 is again reading on internal calibration signal).

8. Verify that digital FREQUENCY meter displays readout of 25.00 KHz.

9. Verify that measurement pp meter reads 10 microseconds.

10. If readings of steps 9 and 10 are as specified, then both input channels and TBE demodulator are functional.

11. Deselect CAL and TBE/SKEW MODE pushbuttons to complete check.

5-11. Check Power Supply Voltages. Before proceeding with calibration, power supply voltages should be verified to eliminate possible repetition of steps caused by misadjusted or faulty power supplies. Power supply voltages are verified by performing the following steps.

a. Preliminary.

1. Perform procedures of paragraph 5-8 (power off) to gain access to test points and adjustments. (See figure 5-1 for locations of all test points and adjustments.)

2. Connect common lead of digital voltmeter (dc range) to horizontal ground bar running across middle of interconnect A1 board. Visually locate connector A3 J3 on power supply A8 board.

b. Procedure.

1. Press POWER pushbutton to on. Observe that panel indicator lights.

2. Connect digital voltmeter input to pin 1 (at top) of power supply connector A8 J3 and verify that voltmeter readout displays +5.000 $\pm$0.005 volts dc.

3. If +5 volt supply is out of tolerance, use adjustment screwdriver and adjust potentiometer A8 R8 on power supply board until voltmeter readout displays +5.000 $\pm$0.005 volts dc. Disconnect voltmeter.

4. Connect digital voltmeter input to pin 3 of connector A8 J3 and verify that voltmeter readout displays +6.00 $\pm$0.30 volts dc. Disconnect voltmeter.

5. Connect digital voltmeter input to pin 5 (reverse polarity) of connector A8 J3 and verify that voltmeter readout displays -6.00 $\pm$0.30 volts dc. Disconnect voltmeter.

6. Connect digital voltmeter input to pin 6 of connector A8 J3 and verify that voltmeter readout displays -12.00 ±0.60 volts dc. Disconnect voltmeter.

7. Connect digital voltmeter input to pin 8 (bottom) of connector A8 J3 and verify that voltmeter readout displays +12.00 ±0.60 volts dc. Disconnect voltmeter.

8. If any power supply output measurement fails to meet any requirement of the previous steps, refer to troubleshooting procedures; if power supply voltages are as specified, continue with next adjustment procedure.

5-12. Microprocessor Clock Adjustment.

a. Procedure.

1. Connect frequency counter to test point A4 TP2 on microprocessor A4 board, using test point A4 TP1 as signal ground.

2. Verify that frequency counter measures 8.000,000 MHz ±10 Hz.

3. If measured frequency is not within specified tolerance, use non-metallic tool and adjust variable capacitor A4 C12 until frequency is within specified tolerance.

4. Disconnect frequency counter.

5-13. Reference Frequency Generator Level Adjustment.

a. Procedure.

1. Connect test oscilloscope to front panel bnc connector marked REF OUT, using coaxial cable terminated with 50 ohms.

2. Verify that oscilloscope displays 3.0 ±0.15 volts pp wave form.

3. If amplitude of displayed wave form is not as specified, use adjusting screwdriver and adjust potentiometer A1 R156 for display of 3.0 ±0.1 volts pp.

NOTE

Depending on user application, an output level different than specified may be desired. Adjustment to a different level does not affect any other calibration step.

4. Use a frequency counter connected to the oscilloscope buffered output with the same oscilloscope setup as described above, and step through all nine operating frequencies (press up or down buttons as required).

5. Verify that outputs exist for each selected frequency and that all are of equal amplitude. (Some rolloff or rounding of output wave form at 200 KHz and 400 KHz is typical.)

6. Disconnect test setup.

5-14. Gain Amplifier Check. Check tracking of the Gain Amplifier by performing the following steps.

a. Procedure.

1. Unplug ribbon cable running from D-MOD A5 board at connector A1 J6 of interconnect board.

2. Select operating conditions at front-panel pushbuttons as follows:

Control	Setting
REF FREQ	200 KHz
LPF BW	10 KHz
MODE	FLUTTER
SIGMA	2σ
RANGE	10%

3. Connect ac voltmeter (HP 400E or equivalent) to DEMOD output bnc connector on front panel.

4. Connect 1 kHz sine-wave source, that has an accurate attenuator, (HP 651B or equivalent) to test point A1 TP18 (use test point A1 TP15 for ground).

5. Set sine-wave source frequency to 1 kHz and set output level for full-scale indication on measurement pp meter (full scale occurs at about 360 millivolts rms input).

6. Verify that DEMOD output level is approximately equal to level of sine-wave source output level.

7. Reduce sine-wave source input by 10 dB using HP 651B attenuator and decrement METER RANGE from 10% to 3% by pressing meter down-arrow pushbutton.

8. Verify that measurement pp meter again reads full scale and that DEMOD output level returns to level read in step 6.

9. Continue reducing input level and down ranging measurement pp meter (pressing down-arrow pushbutton) in 10 dB steps, verifying that measurement pp meter reads full scale and DEMOD output level returns to level read in step 6 for each 10 dB reduction in signal level.

NOTE

Failure to meet criteria of any of above steps is cause for troubleshooting TMA 3000.

Accurate tracking of gain amplifier indicates that TMA 3000 calibration will track from range-to-range.

10. Remove power to TMA 3000, disconnect test setup, and reconnect ribbon cable (removed in step 1) to connector A1 J6 on interconnect board. Leave power turned off for meter zero adjustment, which follows.

5-15. Meter Zero Adjustment.

a. Procedure.

1. Visually examine the measurement pp meter from a 90-degree angle with the meter face at the zero mark (i.e., view straight in to avoid parallax errors) and verify that meter indicator is pointing exactly to the zero graduation mark (lightly finger-tap the meter case to ensure that there is no pointer offset due to friction).

2. If the indicator is not pointing exactly to the zero mark, use adjusting screwdriver to adjust pointer to exactly zero (this adjustment is accessible from the back of the meter case).

5-16. Low-Pass Filter Check.

a. Preliminary.

1. Connect a coaxial cable, with bnc connectors at both ends, between TMA 3000 front panel connectors marked REF OUT and FLUTTER TBE/SKEW.

2. Remove shield from D-MOD A5 board (on underside of microprocessor board tray) to gain access to D-MOD board test points.

3. Press POWER button to on.

4. Set front-panel controls for operation as follows:

Control	Setting
REF FREQ	200 KHz
LPF BW	10 KHz
MODE	FLUTTER
SIGMA	2σ
RANGE	10%

a. Procedure.

1. Use Model HP 651B oscillator as signal source set to 1 kHz, and connect output to test point A5 TP2 of D-MOD board (use test point A5 TP0 for signal ground) to apply test signal to flutter demodulator.

2. Adjust oscillator 1 kHz output for full-scale indication on measurement pp meter. (Note that approximately 1.0 volt rms at A5 TP2 produces a full-scale indication on measurement pp meter.)

3. While maintaining constant oscillator output level, increase oscillator frequency until measurement pp meter indicates 0.707 (i.e., -3dB level). Verify that -3dB frequency is 20 ±1 kHz. (Always approach band edge frequency from lesser frequency.)

4. Repeat step 3 for remaining filter bandwidth ranges (step LPF BW down with down-arrow button to each range) and verify for each range setting that -3dB frequency is within tolerance specified below:

LPF Bandwidth, KHz	-3dB Frequency, Hz
10	±500
5.0	±250
2.5	±125
1.25	±62.5
0.625	±31.3
0.313	±16
0.156	±8

5. Press SERVO TBE/SKEW button to place TMA 3000 in SERVO mode, remove coaxial cable from FLUTTER connector and connect to SERVO TBE/SKEW connector.

6. Move HP 651B oscillator output to test point A5 TP9 (disconnected from A5 TP2) of D-MOD board (use test point A5 TP16 for signal ground).

7. Select LPF BW of 20 kHz, set HP 651B oscillator to 1 kHz and adjust output signal level for full-scale indication on measurement pp meter. Use this 1 kHz output as a 0dB reference for all bandwidth checks to follow and maintain oscillator output at this level for all frequencies without regard for subsequent measurement pp meter readings.

8. Increase oscillator frequency (maintain level of step 7) until measurement pp meter drops to 0.707 (-3dB). Verify that -3dB frequency is 20 ±1 KHz. (In steps to follow, always approach band edge from lesser frequency.)

9. Repeat step 8 for remaining filter bandwidth ranges (step LPF BW down with down-arrow button to each range) and verify for each range setting that -3dB frequency is within tolerance specified below:

LPF Bandwidth, KHz	-3dB Frequency, Hz
10	±500
5.0	±250
2.5	±125
1.25	±62.5
0.625	±31.3
0.313	±16
0.156	±8

NOTE

This completes filter bandwidth tests; failure to meet specifications of any of prior steps is cause to conduct TMA 3000 troubleshooting before continuing. Successful completion of these steps verifies that TMA 3000 data paths are functional and acceptable for procedures that follow. (When filters are checked in the manner described, SERVO bandwidths are typically slightly greater than FLUTTER bandwidths, but are acceptable if specifications are otherwise met.) Do not disconnect test setup.

5-17. Meter Gain Adjustment.

a. Procedure.

1. Leave HP 651B connected to D-MOD board test point A5 TP9 as used in prior checks. Connect digital voltmeter (4-1/2 digits or more on readout) to interconnect board test point A1 TP22 (use mid-board ground bar for signal common).

2. Set oscillator (1 kHz) output level until digital voltmeter (at A1 TP22) reads 4.000 volts dc.

3. Verify that measurement pp meter reads at full-scale deflection. If this meter does not read exactly full scale, use adjusting screwdriver and adjust interconnect board potentiometer A1 R172 for exactly full-scale deflection.

4. Disconnect test setup.

5-18. Sigma Check.

a. Procedure.

1. Connect function generator (Wavetek 143 or equivalent) output to test point A5 TP2 of D-MOD board (use test point A5 TP0 for signal ground).

2. Set LPF BW to 20 KHz range.

3. Adjust function generator to frequency of 300 KHz and select triangular waveform output function.

4. Connect coaxial cable between TMA 3000 bnc connectors REF OUT and FLUTTER TBE/SKEW.

5. Select 2 sigma (2σ) on TMA 3000 and adjust function generator, triangular-wave, output level to produce a .95 indication on measurement pp meter.

6. Select 3 sigma (3σ) and verify that measurement pp meter indicates 1.00 $\pm$0.02.

7. Select 1 sigma (1σ) and verify that measurement pp meter indicates 0.68 $\pm$0.02.

NOTE

Failure to meet specification of steps 6 and 7, indicates a malfunction requiring troubleshooting of the statistical voltmeter circuit.

8. Disconnect test setup.

5-19. Voltage Reference Adjustment.

a. Procedure.

1. Connect digital voltmeter to interconnect board test point A1 TP20 (use ground bus for voltage ground).

2. Verify that digital voltmeter reads out exactly 2.500 volts dc.

3. If measured voltage is not as specified, adjust interconnect potentiometer A1 R173 until reference voltage is within specification.

4. Disconnect test setup.

5-20. TBE/SKEW Gain Adjustment. Because there is no accurate source of TBE/SKEW test signals, the TMA 3000 contains a built-in test signal generator. This internal calibrator derives its signals digitally from a crystal-controlled, reference-frequency oscillator within the TMA 3000. Provided the oscillator and the digital logic are both operational, the calibration generator is accurate to $\pm$0.01 percent or better.

a. Procedure.

1. Place TMA 3000 in TBE/SKEW mode.

NOTE

Choices of REF FREQ and LPF BW switch selections are not important for these tests and may be ignored.

2. Select CAL MODE. (This causes TMA 3000 to automatically select 25 KHz REF FREQ, 2.5 KHZ LPF BW, 1 Sigma, and 10-Microsecond Meter Range.)

3. Verify that measurement pp meter indicates full scale (10 m sec). If meter does not read full scale, adjust potentiometer A5 R70 on D-MOD board for full-scale indication.

NOTE

Variable capacitor A5 C39 is not adjusted in this procedure. This capacitor is normally adjusted in the 1.0 microsecond range and requires a special test signal generator. Should the 1.0 microsecond TBE/SKEW range appear to be out of calibration, or if any component in the TBE measuring circuits require replacement, contact the nearest Bell & Howell field office.

5-21. FLUTTER Gain Adjustment. To effect flutter gain adjustment, perform the following steps.

a. Procedure.

1. Select FLUTTER and CAL modes. (The TMA 3000 automatically goes to 25 KHz REF FREQ, 2.5 KHz LPF BW, 1 Sigma, and 10% analog Meter Range. Calibration signal derived digitally from the TMA 3000 crystal-controlled reference oscillator is introduced into FLUTTER measurement channel.)

2. Verify that measurement pp meter indicates exactly 10% (full scale). If meter does not indicate exactly 10%, then adjust potentiometer A5 R19 on D-MOD board until meter reads exactly 10% (i.e., full scale).

NOTE

The cablibration procedures described in paragraphs 5-14 through 5-17 ensure correct calibration on ranges and filter bandwidths other than those covered in this paragraph. If further calibration points are desired, an appropriate test signal may be generated by frequency modulating a function generator. Most function generators are sufficient as flutter simulators down to approximately 0.1 percent modulation.

5-22. FREQUENCY Meter Check.

a. Procedure.

1. Connect reference frequency output connector REF OUT to FLUTTER TBE/SKEW input bnc connector using short length of bnc-to-bnc coaxial cable.

2. Verify that FREQUENCY meter digital readout displays correct frequency for each of nine frequency selections (i.e., 1.56 KHz to 400 KHz). Failure to produce readout of selected frequencies is malfunction, requiring troubleshooting.

3. Disconnect coaxial jumper cable.

5-23. Analyzer Limits Adjustment.

a. Procedure.

1. Select ANA function and use ANA RANGE up button to select 20 KHz analyzer range (digital readout).

2. Turn front-panel potentiometer fully counterclockwise and verify that FREQUENCY digital meter readout displays 1.95 KHz. If readout is not as specified, adjust interconnect board potentiometer A1 R170 for readout of 1.95 KHz.

3. Turn front-panel potentiometer fully clockwise and verify that FREQUENCY digital meter readout displays 20.5 KHz. If readout is not as specified, adjust interconnect board potentiometer A1 R174 for readout of 20.5 KHz.

4. Because of interaction between adjustments of potentiometers A1 R174 and A1 R170, repeat steps 2 and 3 above until readouts are as specified without additional adjustment.

5-24. Analyzer Adjustments.

a. Procedure.

1. Set TMA 3000 in FLUTTER mode, 200 KHz REF FREQ, 20 KHz LPF BW, 2 Sigma, and 10% Meter Range.

2. Connect REF FREQ output (bnc) to FLUTTER TBE/SKEW input (bnc) with short bnc-to-bnc coaxial jumper cable.

3. Inject 5.00 KHz signal into test point A5 TP2 of D-Mod board (A5 TP0 is signal ground). Adjust signal level as necessary to produce full-scale reading on measurement pp meter (i.e., 10%).

4. Select ANA mode and 2.00 -20 KHz ANA RANGE.

5. Carefully adjust analyzer center frequency to 5.00 KHz.

6. Adjust interconnect board potentiometer A1 R171 to peak TMA analog meter reading.

7. Verify that measurement pp meter peak reading is at 10% (full scale). If meter reading is not at full scale adjust interconnect board potentiometer A1 R167 to produce exactly full-scale (10%) indication.

8. Select INPUT mode. Adjust oscillator to 100 Hz and adjust output level for exactly full scale (10%).

9. Select ANA mode and 10.0 -200.0 Hz range.

10. Adjust front panel potentiometer to peak measurement pp meter reading. (FREQUENCY digital readout should be 100.0 $\pm$5 Hz.)

11. Verify that peak measurement pp reading is 10% (full scale). If peak is not at full scale, adjust interconnect board potentiometer A1 R168 for 10% (full scale).

12. Press REM (remote) button. Verify that FREQUENCY meter digital readout is 205 Hz. If digital readout is not as specified, adjust interconnect board potentiometer A1 R169 for FREQUENCY readout of 205 Hz.

13. Disconnect jumper cable.

5-25. Input Channel Adjustment.

a. Procedure.

1. Place TMA 3000 in FLUTTER mode, 400 KHz REF FREQ, 20 KHz LPF BW, 2 Sigma, and 10% Meter Range.

2. Connect sine-wave oscillator (HP 651B or equivalent) to FLUTTER TBE/SKEW input.

3. Adjust oscillator to 400 KHz and output level to 40 millivolts rms.

4. Turn input Channel 1 trim potentiometer A2 R58 fully clockwise.

5. Visually observe 10% meter range indicator (LED) while slowly turning potentiometer A2 R58 counterclockwise until 10% range indicator begins to flash intermittently. (This sets input sensitivity to 40 millivolts.)

6. Verify sensitivity (A2 R58) adjustment by increasing input level (HP 651B output) to approximately 100 millivolts and then slowly reducing level until 10% range indicator just begins to flash intermittently. Verify that HP 651B oscillator output level is 40 $\pm$4 millivolts.

7. Select SERVO mode and move HP 651B oscillator output to SERVO TBE/SKEW input.

8. Repeat steps 3 through 6, except in steps 4 and 6 potentiometer adjustment will be A3 R58 of input Channel 2 board.

9. Disconnect test setup.

5-26. Input Bandpass Filter Check.

a. Procedure.

1. Connect REF OUT connector to FLUTTER TBE/SKEW connector, using short length of bnc-to-bnc coaxial jumper cable.

2. Select FLUTTER mode, 400 KHz REF FREQ, FRONT, and any other desired condition.

3. Connect oscilloscope to rear panel BPF OUTPUT connector marked FLUTTER TBE/SKEW.

4. Verify that REF FREQ squarewave has been filtered and appears as a sinewave of approximately 3 volts pp amplitude.

5. Step down REF FREQ range, observing that each frequency is present, filtered, and approximately 3 volts pp amplitude.

6. Select SERVO mode and connect REF OUT connector to SERVO TBE/SKEW input. Monitor rear panel BPF OUTPUT connector marked SERVO TBE/SKEW.

7. Repeat steps 2 through 4.

8. Disconnect test setup.

5-27. Rear Panel Inputs.

a. Procedure.

1. Press BACK button (one of SOURCE group).

2. Connect REF OUT connector to rear panel connector marked FLUTTER TBE/SKEW using bnc-to-bnc coaxial jumper cable.

3. Select FLUTTER mode.

4. Repeat bandpass filter check (steps 2 through 4 of paragraph 5-26), except check with rear connectors.

5. Change REF OUT connection to SERVO TBE/SKEW rear connectors and repeat SERVO input check of paragraph 5-26 (steps 5 and 6).

6. Disconnect test setup.

5-28. Tracking Mode Test.

a. Procedure.

1. Connect external oscillator (HP 651B or equivalent) to rear panel FLUTTER TBE/SKEW input connector.

2. Adjust oscillator frequency to 400 KHz and output level to 100 millivolts rms.

3. Set TMA 3000 controls to select FLUTTER mode, BACK source, and reference frequency to TRACK function.

NOTE

TMA 3000 will set its REF FREQ to 400 KHz and acquire input signal within approximately 5 seconds; acquisition is indicated by valid (i.e., non-blanked) frequency readout display and steady (not flashing intermittently) METER RANGE indicator.

4. Change external oscillator frequency to 200 KHz and verify that new frequency is acquired.

5. Step down (down-arrow button) through frequency ranges and adjust external oscillator to any intra-range frequency within each range; verify that TMA 3000 will track changes in input frequency from range to range.

6. Set external oscillator frequency to 200 KHz and wait for TMA 3000 to acquire new signal (approximately 5 seconds, refer to Note in step 3).

7. Slowly increase external oscillator frequency adjustment until either RANGE indicator begins flashing or frequency meter readout blanks off. Verify that external oscillator frequency adjustment is set for 238 KHz or higher.

8. Disconnect test setup.

5-29. FLUTTER Noise Floor.

a. Procedure.

1. Press POWER pushbutton to off.

2. Re-install D-MOD board shield (removed in paragraph 5-16). Fasten shield in place, checking to ensure that shield is insulated from microprocessor mounting tray.

3. Fold microprocesor tray down and install two 8-32 screws to secure tray in place.

4. Connect REF OUT connector to FLUTTER TBE/SKEW connector, press POWER button to on and select: 400 KHz REF FREQ, 20 KHZ LPF BW, FLUTTER mode, and .01% METER RANGE (i.e., most sensitive setting).

5. Verify that indicated flutter is below half scale (0.005%).

6. Step down frequency range, verifying that indicated flutter does not exceed half scale in any range. (Typically, 100 KHz REF FREQ and 20 KHz LPF BW settings produce highest noise floor.)

7. Disconnect test setup.

5-30. INSTRUMENT REASSEMBLY. If no erroneous results occurred during the calibration procedures, operator confidence may be established in TMA 3000 being fully functional and meeting design specifications. The unit can now be reassembled.

a. Procedure.

1. Deenergize TMA 3000.

2. Check that all cables are secured before installing top cover. Install top cover and secure in place with screws.

3. Restore TMA 3000 to normal service readiness.

5-31. TROUBLESHOOTING.

5-32. This subsection contains information to assist the maintenance technician in isolating equipment malfunctions to the functional stage or integrated circuit that is most likely at fault Troubleshooting to discrete components is conventional and depends upon the technician's understanding of the functional theory of the equipment. For this reason, a thorough understanding of the section on TMA 3000 theory is stressed.

5-33. When spare parts and subassemblies (circuit cards or boards) are stocked at the operating site, the replacement of suspected faulty parts or subassemblies with identical components known to be functional is usually the fastest and most reliable method of restoring the equipment to an operational status.

5-34. In the Adjustment and Calibration subsection, a calibration procedure provides the criteria for the proper and specified performance of each function of the TMA 3000. Any fault in the TMA 3000 must necessarily cause a failure to meet one or more of these performance criteria. For this reason, the Adjustment and Calibration procedure (which is also a performance verification test) must be considerd a primary diagnostic process whenever a fault is suspected. Accordingly, the troubleshooting fault isolation is initially based on, and keyed to, those steps that verify specified performance. Any fault caused by out-of-calibration adjustments will be corrected in the normal course of performing the calibration, which is the first step in isolating faults. Appropriately, each fault isolation subject is cross-referenced to the paragraph of Adjustment and Calibration verification.

5-35. INITIAL CHECK. (Reference paragraph 5-10.) Any fault of the initial check, other than minor calibration errors (i.e., errors less than $\pm$10 percent), indicates the presence of a primary fault that must be corrected before continuing. In this event, proceed through the power supply and microprocessor checks (refer to paragraphs 5-36 and 5-37) before attempting to trace the signal through the instrument.

5-36. POWER SUPPLY. (Reference paragraph 5-11.) The power supply should be the first section checked when trouble is suspected, since a supply fault can produce many secondary symptoms. Follow the fault-isolation procedure (reference paragraph 5-72) for troubleshooting power supply faults.

5-37. MICROPROCESSOR CLOCK. (Reference paragraph 5-12.) In the event of an out-of-tolerance frequency or timing period that cannot be corrected into range with adjustment, the microprocessor board crystal (Y1) or the inverter (U11) are suspect. It is always faster and less expensive to replace the inverter (U11) first. Failure of the adjustment capacitor (C12) to produce any response to adjustment is cause to suspect the adjustment capacitor (C12).

5-38. REFERENCE FREQUENCY GENERATOR. (Reference paragraph 5-13.) Absence of any REF generator output (panel BNC REF OUT) suggests a probable fault in one of the following:

- o Microprocessor board devices U11 or U8.
- o Cable from microprocessor board connector (J6) to interconnect board connector (J7).

- o Interconnect board devices Q12, Q13, U52-U55, Q14, Q15 or components associated with these devices.

- o Coaxial cable from interconnect board (E13, E14) to REF OUT BNC connector.

- o REF OUT BNC connector.

Incorrect or missing frequencies indicate problems in the countdown divider (U53) or the data selector (U55) on the interconnect board. Adjustment or level problems may be caused by faulty transistors Q14 or Q15 on the interconnect board.

5-39. GAIN AMPLIFIER. (Reference paragraph 5-14.) Failures of the gain amplifier checks are related to low-pass filter circuitry on the interconnect board. Gross tracking errors indicate possible failures in data selectors U31 (3%, 1%, 0.3%) or U29 (0.1%, 0.03%, or 0.01%). Tolerance errors may be related to out-of-tolerance resistor dividers R92-R95 (3%, 1%, 0.3%) or R82-R85 (0.1%, 0.03%, 0.01%).

5-40. METER ZERO. (Reference paragraph 5-15.) Inability to adjust the mechanical zero of the deenergized meter is caused by a defective meter. In some instances a faulty meter mechanism can be functionally restored by turning the zeroing adjustment fully in both directions and then rezeroing the movement. Otherwise, replacement of the meter is required.

5-41. LOW-PASS FILTER. (Reference paragraph 5-16.)

NOTE

This check applies to portions of the D-MOD board and to the interconnect board low-pass filter section. (See schematic shown on Sheet 3 of figure 7-6.)

5-42. Frequency response errors can result from components changing value to out-of-tolerance, such as 1-percent resistors that scale bandwidths or capacitors that determine fundamental pole locations for all bandwidths. Faulty data selectors that switch in precision components can also cause out-of-tolerance variations.

5-43. Errors that only occur on a single bandwidth are usually due to a faulty component in one of the resistor networks (i.e., resistor RN1 on the D-MOD board or resistors RN1-RN4 on the interconnect board).

5-44. Several data selectors are used to determine low-pass filter characteristics; failure of any one of the data selectors can cause frequency response errors.

a. Flutter Mode.

1. Data selectors U2 and U11 (on the D-MOD board) select poles in the filter characteristic. Data selectors U36-U39 (on the interconnect board) select additional poles in the filter.

b. TBE/Skew Mode.

1. Only selector U11 on the D-MOD board affects the frequency response. Selectors U36-U39 on the interconnect board are also active.

2. All data selectors on the interconnect board (i.e., U36-U39) select inputs to operational amplifier summing junctions. Therefore, the selected input has a relatively small signal level (compared to unselected inputs) and may be identified by using only an oscilloscope. For each filter bandwidth, one (and only one) input is selected, with the 2.37 k-ohm resistor selected for 30 kHz, 4.87 k-ohms for 10 kHz, etc. Comparing the selected channel with the expected may identify a faulty selector or defective selection logic. On the D-MOD board, data selector U2 (flutter) switches to ground, but selector U11 does not. The selected channel of selector U11 (or any of the selectors) may be identified by using a volt-ohm meter; i.e., the selected channel exhibits a resistance between the selector input and output (pin 3) of less than 500 ohms.

3. A resistor suspected of being in error is best checked by selecting a bandwidth in which the resistor is not selected and measuring the suspect resistor with an accurate digital voltmeter. All resistors in the precision networks should be within ±1 percent of their nominal resistance.

4. Bandwidth errors that appear on all bandwidths may be caused by faulty capacitors or faulty damping resistors (R80, R65, R90, R89 on the board).

5. If another TMA 3000 is available, a point-to-point comparison between this and the malfunctioning unit can provide significant indications pointing to the faulty component. Otherwise, a call to the nearest Bell & Howell field service office for assistance is recommended.

5-45. METER GAIN. (Reference paragraph 5-17.) Inability to produce a full-scale meter deflection can be caused by an out-of-tolerance resistor (R146, R172, or R147), a defective meter, or a problem in the cable between the interconnect board (J8) and the display board (J1). Another possible cause of low meter readings can be a poor solder connection in the leads from the display board (E3, E4) to the meter.

5-46. Excessively high meter readings are most likely caused by an out-of-tolerance resistor (R146, R172, or R147) or by a faulty meter.

5-47. SIGMA CHECK. (Reference paragraph 5-18.) Errors in the sigma check of a few percent are most likely caused by tolerance errors in the sigma resistors R104 and R130 (1 sigma), R108 and R134 (3 sigma), or R106 and R133 (both 1 sigma and 3 sigma).

5-48. Errors greater than a few percent probably indicate malfunctions in the analog switches (U45 and U49) or in the comparators (U46 and U50). An oscilloscope check, to verify that the corresponding comparators are functioning, can aid in locating the faulty circuit.

5-49. VOLTAGE REFERENCE. (Reference paragraph 5-19.) A grossly out-of-tolerance measurement on test point TP20 is probably caused by one or more of the following components being faulty: U48, VR1, R116. Smaller errors can be caused by the following components being faulty: CR19, R173, CR20. (All the above components are located on the interconnect board, sheet 5 of figure 7-6.)

5-50. TBE/SKEW GAIN. (Reference paragraph 5-20.) Inability to adjust trim potentiometer R70 to produce a full-scale meter reading can be caused by a large number of faults. As a first check, measure the timing ramp at test point TP13 with an oscilloscope. A negative-going ramp starting from +6 volts (-1, +2 volts) and terminating near 0 volts should be measured. Because of alternating ramp time periods, the lower end of the ramp will terminate at two distinct levels: approximately 3 volts pp and approximately 4 volts pp.

5-51. After sampling by Q8, the signal at test point TP8 should be a square wave of 3-4 volts pp. Some degree of stepping at the transition may be observed. Additional attenuation occurs in the programmable gain scaler (RN2, U14, U20, and U16), which results in a rounded square wave of 100 millivolts pp measured at test point TP7.

5-52. FLUTTER GAIN. (Reference figure 5-21.) In the flutter CAL mode, the signal at test point TP7 (D-MOD board) should be rounded square wave of approximately 1 volt pp. If potentiometer R19 cannot be adjusted to produce a full-scale meter indication, then a check of the signal level at test point TP7 can be used to locate the problem. Moving back to test point TP1, a similar square wave (but with about 20-percent carrier frequency level) can be seen. The dc level at test point TP1 should be 0 $\pm$0.02 volts. A significant departure from zero indicates problems in the timing-capacitor selector (U9 on the D-MOD board) or in the automatic frequency control (U6 pins 12, 13, 14).

5-53. FREQUENCY METER. (Reference paragraph 5-22.) A frequency meter reading of zero usually indicates that no signal is conducted to the frequency meter IC (U6 on the display board). This may be caused by problems in the input channel, on the interconnect board, in the cable from the interconnect board (J8) to the display board (J1), or to a faulty frequency-meter chip (U6). Use an oscilloscope to trace the signal point-to-point through this path until the faulty circuit is located. Erratic or incorrect frequency readouts are usually because of a faulty IC chip or insufficient signal levels along the signal path.

5-54. ANALYZER LIMITS. (Reference paragraph 5-23.) A non-functional analyzer (zero or very low frequency) is usually caused by a faulty oscillator (U27 on the interconnect board) or possibly the dc conditioning circuits (U25, U24). Failure to achieve the 20.5 kHz setting may be traced to U27, U32, or U41, or to the dc circuits. Historically, variations between type 14528 CMOS one-shots from different manufacturers has been wide and experience has shown that only those manufactured by Motorola fall dependably within acceptable limits.

5-55. ANALYZER ADJUSTMENTS. (Reference paragraph 5-24.) Failure to peak the analyzer by using potentiometer R171 can be caused by a faulty one-shot (U41) or problems within the sampled state-variable filter (U17, U11, U21, and U22). The pulse width at the output of U41 is normally approximately 650 nanoseconds. A pulse that cannot be adjusted to this width indicates a problem in U41 or its associated components. If the correct pulse width can be produced, it is necessary that the signal be traced through the sampled filter.

5-56. If problems occur in setting potentiometers R167 or R168, these may be caused by components (within the sampled filter) being out of tolerance or faults in U11 or U21.

5-57. If the analyzer cannot be set to 205 Hz in the REM mode, verify that the inputs to U18 are all high (TTL true) and that the output of U25 (pin 14) is approximately equal the voltage measured at the top of the front panel FREQUENCY potentiometer (R175). If this is the case, data selector U40 may be defective. Otherwise, U13, U18, U25, or their associated components can be at fault.

5-58. INPUT CHANNEL. (Reference paragraph 5-25.) Problems with the input channel low-level adjustment may be caused by a faulty photo modulator VTLI (particularly if the lower limit is too high), Q4, Q5, Q3, or U2. If the low level cannot be obtained, it may be possible to reduce resistor R14 to 510 and thus meet the requirements.

5-59. INPUT BANDPASS FILTER. (Reference paragraph 5-26.) Unfiltered or insufficient output levels indicate that incorrect filter components are being selected or that the AGC is not functioning properly. If necessary, trace the signal through the filters, using the theory of operation as a guide. (The comments regarding data selectors, found in paragraph 5-44, may be helpful in isolating faulty components.)

5-60. REAR PANEL INPUTS. (Reference paragraph 5-27.) Incorrect selection of inputs can be caused by faulty input buffers (Q3-Q6), data selectors (U4), or logic buffer (U5), all located on the interconnect board.

5-61. TRACKING MODE. (Reference paragraph 5-28.) Problems in the tracking mode test usually are caused by faults in the input channel AGC or the low-pas filter, the frequency meter, or the input data selector.

5-62. FLUTTER NOISE FLOOR. (Reference paragraph 5-29.) Excessive noise in the flutter output can usually be traced to the D-MOD board and to the ICs immediately around the demodulator. In order of being suspect: U4, U8, U7, and U3. (A set of integrated circuits, selected for their low noise, is available from Bell & Howell for this application.)

5-63. TROUBLESHOOTING AIDS.

5-64. SELF TEST. Several self-test functions are designed into the TMA 3000. The first of these is automatically run when the unit is initially powered up (following each deenergized state).

5-65. ROM TEST. A CHECKSUM routine adds each of 4096 locations of the control ROM (read-only memory) and compares the sum to a preset value. A comparison error indicates a change in the ROMs, which can cause a failure in the TMA operation. If the ROM test fails, the processor is halted, which prevents any operation.

5-66. VOLTAGE TEST. Each of the TMA 3000 five power supply voltages is measured using the internal analog-to-digital (A/D) converter. If any of the supplies is not within ±10-percent of its nominal value, an error is indicated and a system reset is generated. This then repeats the initialization sequence, including ROM and voltage tests. A persistent error in the voltage test causes the front panel indicators to flash on and off intermittently and front panel mode controls will not respond to any operator manipulations (e.g., pressing pushbuttons will not cause a response).

5-67. As a diagnostic, the power-on self-test is limited, since it presumes an operational microprocessor and at least a properly-operating +5 volt power supply (i.e., failure of either of these will prevent a successful self-test routine). However, successful completion of a self-test provides operator confidence in subsequent TMA 3000 operations.

5-68. CAL TEST. Built-in calibration signals for both flutter and TBE/skew modes provide a first-order check of most TMA circuitry, from the input of the signal-conditioning channels to the front-panel meter.

5-69. Pressing the front panel CAL pushbutton to the FLUTTER mode causes the TMA to select FLUTTER CAL, setting the REF FREQ (KHz) to 25 KHz, LPF BW (KHz) to 2.5 KHz, sigma to 1 sigma (1σ), and METER RANGE to 10%. A crystal-controlled, digitally synthesized flutter signal will be applied at the input to channel 1. The signal is then AGC'd, band-pass filtered, limited, demodulated, low-pass filtered, and measured the same as any other input. A properly calibrated instrument will then read exactly 10 percent pp flutter. Small departures (±3 percent) can be assumed to be normal variations, larger errors (from ±3 to ±10 percent) indicate the need for recalibration, and readings that vary more than 10 percent usually indicate more serious problems.

5-70. Pressing CAL pushbutton to the TBE/skew mode will similarly apply two digitally phase-modulated signals to the two input channels. The resultant meter readings should be 10 microseconds pp and 25.00 kHz frequency.

5-71. DIAGNOSIS OF FAILURES.

5-72. POWER SUPPLY TROUBLESHOOTING. A failure of any kind in the power supply self-test should be followed by a check of the power supply voltages. The power supplies can be electrically accessed on the power supply board connectors J2 and J3 at the following listed connector pins.

J2/J3 Pins	Wire Color	Supply Voltage
1	Green	+5V
2	Black	Ground (digital)
3	Blue	+6 V
4	Black	Ground (analog)
5	White	-6 V
6	Violet	-12 V
7	Black	Ground (analog)
8	Red	+12 V

5-73. All supplies track a single reference (+5 volts) and should regulate to within ±5 percent of the nominal voltage (voltages are typically within ±2 percent of nominal). If any power supply output is out-of-tolerance, monitor the +5 volt supply and adjust trim potentiometer R8 (on the power supply board) for 5.00 ±0.05 volts output. If the out-of-tolerance condition continues, a check of the power supply is indicated.

5-74. The +5 volt section of the power supply is protected by both a short-circuit current limiting and an overvoltage crowbar. If the +5 volts is pulled down to a voltage between 1.5 volts and 5 volts, an external overload fault probably exists. If the low voltage continues and the voltage drop across resistor R1 is greater than 0.3 volt, the series regulator (Q1, located on the rear panel) is suspect. If the voltage returns to about +5 volts, an overload on one of the loads is indicated. Turning power off, unplugging cables from connectors J2, J3, and J4, then turning power on will identify which.

5-75. The +6 volt and +12 volt supplies are referenced to the +5 volt reference from U1 (a type LM723). These power supplies are short-circuit protected by internally limiting the output devices (MC 7805) to about 1.2 amperes. The -6 volt and -12 volt supplies are referenced to their positive counterparts and are similarly short-circuit protected by MC 7905 regulators.

5-76. MICROPROCESSOR TROUBLESHOOTING. A power-on failure that leaves the front panel indicators unlighted or very dimly lighted can be caused by the microprocessor. Several basic tests may be used to indicate the cause of failure (assuming that the power supply has been verified as not defective).

a. Clock

1. Monitor test point TP2 (microprocessor board) with an oscilloscope and low-capacitance probe. Verify that the TP2 signal is an 8 MHz TTL square wave. Similarly, check pin 1 of the 8085A (U15) for a 4 MHz TTL square wave. For this test, the presence of a clock of the correct amplitude and an approximate frequency is adequate.

2. If an acceptable clock signal is not measured at test point TP2, the crystal oscillator is defective. Presence of the clock at test point TP2, but not at pin 1 of U15 indicates a probable failure of U10, U9, or U15.

b. Activity.

1. If the clock is present, monitor the lowest order data/address line, AD Ø (pin 12 of U15). A steady logical high level indicates a HALT state, indicating that the ROM test ended in failure. Verify that RESET IN/(pin 36 of U15) is not low and that HOLD (pin 39 of U15) is not high.

2. Monitor the AD Ø line again and turn the TMA off. Wait for 10 seconds and turn the TMA on. A brief burst of activity and then a steady high confirms a ROM test failure.

3. If the activity test shows activity, but the non-indicating front panel continues, examine the activity pattern: In a correctly operating system, activity occurs in bursts of 3-10 milliseconds (approximately). Continuous steady activity or a lower than indicated repetition rate indicates potential problems in the microprocessor, reset circuit, or the interrupt timer in the 8155. Use a clip lead to ground pin 36 of U15 (RESET IN/) momentarily. If normal operation resumes, the power-on reset circuit is suspect. Elements of the power-on reset circuitry are U19, U21 (pins 1-3), U20 (pins 13 and 12), C18, R16, and R15. R21, CR1, and C25 also contribute to power-on reset operation.

4. Fault indications beyond this point are not recommended for those without microprocessor servicing experience.

5-77. INPUT CHANNEL TROUBLESHOOTING. The input channel boards are identical and may be interchanged to improve the accessibility of test points and signal paths. The channel 2 board may also simply be removed to provide access to channel 1 board (which is otherwise obstructed to easy access).

CAUTION

Exercise extreme care in replacing the input channel boards to ensure that the contact pins are properly guided into the receptacle. Otherwise, pins are easily bent out of alignment or jammed into an adjacent socket position.

5-78. An input signal may be traced from the input connector (verify correct signal source, front or back, is selected) to TP1, through AGC amplifier (U1) to TP2 and through the low-pass and high-pass filters (which make up the input band-pass filter). The signal at test point TP9, if within the filter frequency range, will be maintained at a constant 3.0 volt pp level by the AGC. Signals that are too small for the limited range of the AGC amplifier, or are outside the filter bandwidth, will cause comparator U2 output to go logically low, disabling the limiters and pulling the PC line logically high to signify that no valid signal is being received at the input.

5-79. The limiter output should be a square wave of the input frequency and an amplitude of approximately 12 volts pp, centered about zero volts.

NOTE

- In the flutter mode, only channel 1 is active; channel 2 is disabled via the AMP DIS input (pin 9).
- In the TBE/skew mode, both channels are active.
- In the SERVO mode, only channel 2 is active, with the AGC and filter sections bypassed through U3 on the interconnect board, and the input signal is applied directly to the limiter input.

5-80. FLUTTER SIGNAL DIVIDER TROUBLESHOOTING. For reference frequencies of 200 kHz or 400 kHz, the flutter signal is divided by 2 or 4, respectively, to 100 kHz (nominally). The frequency division and selection are performed (on the interconnect board) at U15 and U9, with U6 functioning as a buffer.

5-81. REPAIR.

5-82. Repair of the TMA 3000 is normally considered beyond the scope of organizational level maintenance, but within the capability of intermediate level maintenance facilities.

5-83. Repair of the TMA 3000 should be attempted only by technicians experienced in the techniques of de-soldering and soldering on high-density printed-circuit boards. Most of the components in the TMA 3000 are soldered in and must be tested in place and, if necessary replaced by soldering a new item into the board.

5-84. The following few common-sense rules will help to minimize the cost, frustration, and risks of repair:

a. If several components are suspect, replace the lowest cost (or most readily available) one first.

b. When in doubt, adding a socket will ease choice of ICs subject to selection.

c. When removing a bad or suspect IC, it is recommended that the leads be cut and removed, one by one, rather than to risk damaging the PC board to remove a defective IC intact.

d. Even "shotgunning" techniques (replacing every IC that might possibly cause a given problem) is faster and less expensive than sending an instrument in for factory service. This assumes that the shotgunning can be accomplished without damaging the PC board.

e. Replacement of PC boards or modules is also faster and less expensive than factory service.

5-85. REPAIR PROCEDURES.

5-86. Repair procedures are limited to the direct replacement of defective assemblies, subassemblies, and major piece parts with functional components known to be operating properly.

a. General Procedures.

1. Remove four Phillips-head screws that secure the top cover. Do not remove the nickel-plated screws in the front-panel hold-down rail at this time.

2. Remove two 8-32 screws (through its aluminum tray) securing microprocessor board. Carefully tilt the tray back to allow the phenolic-support leg to fall back to rest on the top of the power transformer. (This will support the microprocessor tray and prevent damage to any of the components.)

NOTE

With the tray folded back, access to the TMA 3000 interior is possible.

3. If required, unplug the two input channel conditioner boards and remove each by pulling each board straight up.

CAUTION

The input channel board connector pins on the interconnect board are long and easily bent. In replacing the input board, take care to ensure that all pins are properly engaged and that none is bent or pushed out of the way.

4. Remove two 4-40 screws securing the aluminum shield that protects D-MOD board from electrical noise.

b. Front Panel Disassembly.

1. Remove two nickel plated 8-32 oval head screws that secure the front-panel hold-down rail.

2. Tilt front-panel assembly forward. (Adequate service loops have been provided on all front-panel cables to allow the panel to lay face-down in front of the instrument.)

NOTE

With the front panel in this position, it is possible to replace the BNC connectors. Replacement of display-board components, frequency potentiometer, frequency display, analog meter, or any of the display LEDs requires further disassembly.

3. Remove display board (fastened to studs inserted in the front panel) by removing the 4-40 nuts on these studs and unsoldering the frequency potentiometer and analog meter leads. Also, remove the knob from the frequency potentiometer. Lift the display board off the front panel, taking care not to lose the spacers (which locate the board relative to the panel).

c. Rear Panel Assembly.

CAUTION

The isolated BNC connectors have a plastic threaded housing to preserve electrical isolation. These connectors should not be replaced with conventional BNCs. Use extreme care in installing the replacement connectors, for they are easily damaged by excess torque. Always use the extra thick nuts to distribute the hold-down forces over several threads.

1. The rear panel should not need to be removed since the four isolated BNC connectors and the series-pass power transistor may be replaced with the panel in place.

d. Interface Boards.

1. The IEEE 488 and RS-232C interface boards are permanently mounted to metal plates, which, in turn, are fastened to the rear panel by four 6-32 screws. The interface assemblies are connected to the connector J2 on the microprocessor board by a single 34-conductor cable.

2. Installation of a new interface board requires only that the metal trim plate (or old interface) be removed and the new interface be installed in its place. The 34-conductor cable plugs into the microprocessor board. IEEE 488 address switches must be configured as must RS-232C baud-rate switches.

e. Microprocessor Board.

1. Disconnect all of the ribbon cables (J1, J3-J6, and, if applicable, J2) and the power cable J8.

2. Remove nine 4-40 screws securing the microprocessor board to its mounting tray and remove board.

f. D-MOD Board.

1. Disconnect 20-pin ribbon cable from D-MOD board (connecting to the interconnect board).

2. Remove four 4-40 screws holding D-MOD board in place on the bottom of microprocessor tray.

NOTE

After re-installing the board, be sure to replace the shield, as this helps to eliminate noise pick-up in the sensitive demodulator circuits.

g. Power Supply.

1. Unplug the three dc distribution cables (J2-J4) and the ac cable (J1). The cable to the rear panel-mounted series-pass transistor (Q1) may be disconnected by slipping the transistor connector off while the transistor is still in place.

NOTE

Four three-terminal regulators (VR1-VR4) are screw-mounted to the heat-sink block at the front of the power supply board. These regulators plug into four sockets at the front edge of the board. With care, the board may be removed without removing the regulators. Should the regulators be removed, be sure not to lose the heat-conducting (and electrically insulating) fibre thermo-pads.

2. Remove five 4-40 screws securing power supply to right-side panel and remove power supply.

h. Reassembly Procedures.

1. Reassembling the TMA 3000 is accomplished by simply reversing the disassembly process. Take care to install all connectors and hold-down screws.

2. If the microprocessor board was removed, be sure the ground lug (if used) at the center-front of the board is secured.

NOTE

Do not over-tighten the cover hold-down screws as this could distort the cover unnecessarily.

5-87. FACTORY REPAIR SERVICE.

5-88. At the user's option, instruments (or major assemblies) may be returned to the factory for repair. When an instrument or assembly is returned:

a. Indicate the symptom of defect. State as completely as possible, both on an instrument tag and on the order form, the nature of the problem encountered. If the trouble is intermittent, please be specific in describing the instrument's performance history.

b. Include special instructions, if any. If any changes in the instrument or assembly have been made, and it is desired to retain the modified form, please indicate this specifically.

c. State the desired invoicing procedure. In the first correspondence, indicate whether repair work may begin immediately with billing in accordance with the standard pricing system, or whether Bell & Howell should secure prior approval of the price before proceeding with the repair. The price will be the same in both cases, but any delay will be minimized by permission to start work immediately. The order acknowledgment copy will, of course, always show the price.

d. Pack securely and label. Proper packaging saves money. The small amount of extra care and time it takes to cushion a part or instrument properly may prevent costly damage while in transit. Make certain that the address is both legible and complete; failure to do so often results in needless delay. Address all shipments and correspondence to:

Bell & Howell Company
DATATAPE Division
300 Sierra Madre Villa Avenue
Pasadena, California 91109

Attention: Repair Department

e. Show return address on repair correspondence. Please indicate clearly the exact address to which the equipment should be returned after repair is completed. All shipping costs will be borne by the owner of the equipment, not by Bell & Howell.

SECTION VI

PARTS LIST

6-1. INTRODUCTION.

6-2. A parts list and illustrations (figures 6-2 through 6-5) for the TMA 3000 Tape Motion Analyzer, identified by Bell & Howell part number 552100, are included in this section of the manual. The manufacturers are identified by the Federal Supply Code for Manufacturers, Cataloging Handbook H 4-2 and as listed in table 6-1. The absence of a code number preceding a part number in the parts list indicates that the part is a Calaway and Brooks part. The parts list (table 6-2) includes the following entries:

A. An item number denoting the sequence of line items on each page (ITEM NO. column).

B. A description, including the noun name and modifier(s) for each line item, followed by a listing of the principal characteristics -- electrical or mechanical, when pertinent (DESCRIPTION column).

C. The quantity of the listed component used in the subject assembly (QTY column).

D. The figure number of the illustration showing the physical location of the line item component (FIG./INDEX OR REF SYM column).

E. The figure index (locator) number or the schematic reference designator number of the line item component -- entry will list whichever is shown on the figure -- (FIG./INDEX OR REF SYM column).

F. The manufacturer or supplier of the line item component as identified by the five-digit Federal Supply Code for Manufacturers (FSCM) taken from Cataloging Handbook H 4-2 (MFR CODE column). A code consisting of letters and zeros will be used when no FSCM code is available.

G. The manufacturer's or military part number for the line item component (MFR OR MIL PART NO. column).

6-3. PARTS LIST LEGEND FIGURE.

6-4. Figure 6-1 illustrates a typical parts list page with lettered identifiers corresponding to the descriptive paragraphs above.

6-5. ORDERING REPLACEMENT PARTS.

6-6. Parts should be ordered through the nearest Bell & Howell DATATAPE Division Sales and Service Office. Price and delivery information on parts or complete instruments may be obtained there also. To assist in making this contact, a list

of Sales and Service Offices is included in the front of this manual. When ordering parts, the following information should be supplied to our field office engineers:

a. A description of part or assembly, obtained from the parts list.

b. The manufacturer part or assembly number, also in the parts list, or on the component proper.

c. The schematic symbol, given on the cabling diagram and on the parts list.

d. The part or assembly type number, shown on the instrument nameplate.

e. The production serial number also on the nameplate.

f. The Bell & Howell register number, applying to the complete system.

Table 6-1. Parts List for the 802558-C001 and 802558-0002 FM Reproduce Amplifiers (Sheet 1 of 15)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	FM REPRODUCE AMPLIFIER ..... 1-7/8 THRU 60 IPS, WB GP I	1	6-2	14028	802558-0001
2	FM REPRODUCE AMPLIFIER ..... 3-3/4 THRU 120 IPS, WB GP I	1	6-2	14028	802558-0002
3	. PRINTED WIRING BOARD	1	6-2/1	14028	801594
4	. OVEN, ONE-SHOT	1	Y2	14028	802578
5	. CAPACITOR, FIXED, TANTALUM ..... 1.0 µF ±20%, 50 Vdc	4	C21,22,30, C31	80357	T330A105M050AS
6	. CAPACITOR, FIXED, TANTALUM ..... 2.2 µF ±20%, 35 Vdc	8	C12,13,14, C23,24,26, C32,33	80357	T330A225M035AS
7	. CAPACITOR, FIXED, TANTALUM ..... 2.7 µF ±20%, 35 Vdc	2	C39,40	80357	T330A275M035AS
8	. CAPACITOR, FIXED, TANTALUM ..... 6.8 µF ±20%, 20 Vdc	2	C27,28	80357	T330A685M020AS
9	. CAPACITOR, FIXED, TANTALUM ..... 10 µF ±20%, 1 Vdc	3	C15,29,37	80357	T330A106M010AS
10	. CAPACITOR, FIXED, TANTALUM 4.7 µF ±20%, 25 Vdc	3	C34,38,41	80357	T330A475M025AS
11	. CAPACITOR, FIXED, TANTALUM ..... 15 µF ±20%, 25 Vdc	2	C9,11	05397	T330C156M025AS
12	. CAPACITOR, FIXED, TANTALUM ..... 15 µF ±10%, 10 Vdc (USED ON 802558-0001)	1	C6	80357	T330A156K010AS
13	. SHIELD, PWB	1	6-2/20	14028	801179

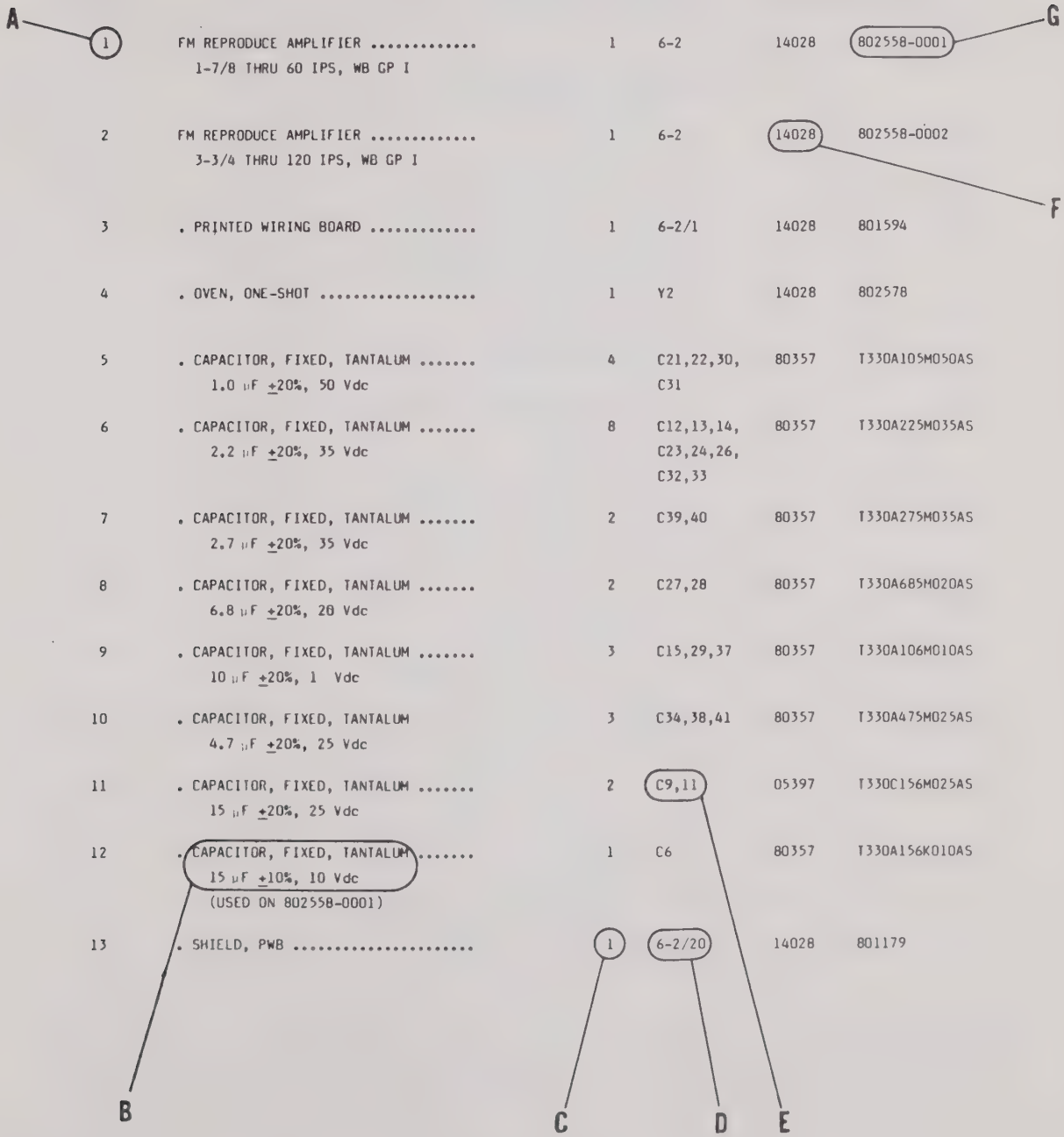


Figure 6-1. Parts List Legend

CODE	MANUFACTURER
(To be assigned)	Calaway and Brooks Pomona, California
A000A*	Temple Industries Tecate, California
A000B*	Berquist Edina, Minnesota
01002	General Electric Company Capacitor Products Dept. Hudson Falls, New York
01121	Allen-Bradley Company Milwaukee, Wisconsin
01295	Texas Instruments, Incorporated Semiconductor Group Dallas, Texas
02660	Bunker Ramo Corporation Amphenol North American Division Broadview, Illinois
02735	RCA Corporation Solid State Division Somerville, New Jersey
04713	Motorola Semiconductor Products, Incorporated Phoenix, Arizona
05394	PEM Machine and Tool Company, Incorporated Cranford, New Jersey
06540	Mite Corporation New Haven, Connecticut
06915	Richco Plastic Company Chicago, Illinois

*These vendors are not listed in the Federal Supply Code for Manufacturers Cataloging Handbook H 4-2.

Table 6-1. List of Manufacturers (Sheet 1 of 4)

CODE	MANUFACTURER
07263	Fairchild Camera and Instrument Corporation Mountain View, California
08261	Spectra-Strip, An Eltra Company Garden Grove, California
14028	Bell & Howell Company DATATAPE Division Pasadena, California
14433	I.T.T. Semiconductors Division West Palm Beach, Florida
15238	I.T.T. Semiconductors Division Lawrence, Massachusetts
15801	Fenwal Electronics Farmingham, Massachusetts
16428	Belden Corporation Richmond, Indiana
19477	ETI Oceanside, California
21604	Buckeye Stamping Company Columbus, Ohio
22526	E.I. Dupont de Nemours and Company Berg Electronics Division New Cumberland, Pennsylvania
24546	Corning Glass Works Bradford, Pennsylvania
27014	National Semiconductor Corporation Santa Clara, California
27264	Molex, Incorporated Lisle, Illinois
31745	Rogers Corporation Chandler, Arizona
32171	Modutec, Incorporated Norwalk, Connecticut

Table 6-1. List of Manufacturers (Sheet 2 of 4)

CODE	MANUFACTURER
32293	Intersil Incorporated Subsidiary of General Electric Company Cupertino, California
32559	Bivar, Incorporated Irvine, California
33297	N E C Mountain View, California
34649	Intel Corporation Aloha, Oregon
46711	CTS of Berne, Incorporated Berne, Indiana
49956	Raytheon Company Lexington, Massachusetts
50440	Hewlett-Packard Company Mountain View, California
52840	Western Digital Corporation Costa Mesa, California
53673	Thomson - CSF Components Corporation Canoga Park, California
55680	Nichicon-America Corporation Schaumburg, Illinois
56117	Aries Electronics, Incorporated Frenchtown, New Jersey
56289	Sprague Electric Company North Adams, Massachusetts
59730	Thomas and Betts Corporation Iowa City, Iowa
71279	Cambridge Thermionic Corporation Cambridge, Massachusetts
72136	Electro Motive Corporation Subsidiary of International Electronics Corporation Florence, South Carolina

Table 6-1. List of Manufacturers (Sheet 3 of 4)

CODE	MANUFACTURER
72699	General Instrument Corporation Clifton, New Jersey
73445	Amperex Electronic Corporation Hicksville, Long Island, New York
75915	Littelfuse, Incorporated Des Plaines, Illinois
80031	Mepco-Electra, Incorporated Morristown, New Jersey
80294	Bourns Instruments, Incorporated Riverside, California
80740	Beckman Instruments, Incorporated Fullerton, California
81073	Grayhill, Incorporated La Grange, Illinois
82389	Switchcraft, Incorporated Subsidiary of Raytheon Company Chicago, Illinois
82893	Vector Electronics Company, Incorporated Sylmar, California
83330	Herman H. Smith, Incorporated Manasquan, New Jersey
86797	Rogan Corporation Northbrook, Illinois
91637	Dale Electronics, Incorporated Columbus, Nebraska
91833	Keystone Electronics Corporation New York, New York
96918	Kings Electronics Company Tuckahoe, New York

Table 6-1. List of Manufacturers (Sheet 4 of 4)

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 1 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	TMA 3000 TAPE MOTION ANALYZER	REF	6-2	14028	552100
2	. MAIN CHASSIS	REF	6-2	14028	552100-1000
3	. . FRONT PANEL ASSY	1	6-2/1,6-3	14028	552100-2000
4	. . REAR PANEL ASSY	1	6-2/2,6-5	14028	552100-3000
5	. . UNIT ASSY, POWER SUPPLY, ... SIDE PLATE, RIGHT	1	6-2/3,6-6	14028	552100-4000
6	. . UNIT ASSY, MICROPROCESSOR/ ..... D-MOD	1	6-2/4,6-7, 6-8	14028	552100-5000
7	. . INTERCONNECT BOARD ASSY	1	6-2/5,6-9	14028	552100-6000
8	. . CARD GUIDE SUPPORT	2	6-2/6		3057
9	. . CARD GUIDE	4	6-2/7		3074
10	. . INPUT CHANNEL CONDITIONER ASSY .	2	6-2/8,6-10	14028	552100-9000
11	. . CROSSRAIL, REAR	1	6-2/9		3059
12	. . CROSSRAIL, FRONT	1	6-2/10		3060
13	. . SIDE PLATE, LEFT	1	6-2/11		3025
14	. . GROUND SPRING	2	6-2/12		3070
15	. . CABLE, POWER SUPPLY ..... MICROPROCESSOR, 6 WIRE	1	6-2/13		3072-2
16	. . CABLE, POWER SUPPLY ..... MICROPROCESSOR, 8 WIRE	1	6-2/14		3072-1
17	. . CABLE, POWER SUPPLY ..... XFRMR, 6 WIRE	1	6-2/15		3072-3
18	. . CABLE, POWER SUPPLY ..... DISPLAY, 2 WIRE	1	6-2/16		3072-4

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 2 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CABLE, UP - INTERCONNECT, ... 10 PIN	1	6-2/17		3071-2
2	. . CABLE, UP - INTERCONNECT, ... 20 PIN	1	6-2/18		3071-1
3	. . CABLE, UP - INTERCONNECT, ... 20 PIN	1	6-2/19		3071-1
4	. . CABLE, UP - DISPLAY, ... 20 PIN	1	6-2/20		3071-4
5	. . CABLE, UP - KEYBOARD, ... 20 PIN	1	6-2/21		3071-5
6	. . CABLE, D-MOD - INTERCONNECT, ... 20 PIN	1	6-2/22		3071-1
7	. . CABLE, INTERCONNECT - DISPLAY, . 10 PIN	1	6-2/23		3071-2
8	. . SCREW, 6-32 x 3/4 FLAT HEAD .... PHIL BLACK OXIDE	4	6-2/24		
9	. . SCREW, 6-32 x 1/4 PAN HEAD ..... PHIL	2	6-2/25		
10	. . SCREW, 6-32 x 3/8 PAN HEAD ..... PHIL	4	6-2/26		
11	. . SCREW, 6-32 x 1/2 PAN HEAD ..... PHIL	2	6-2/27		
12	. . SCREW, 8-32 x 1/2 PAN HEAD ..... PHIL	2	6-2/28		
13	. . SCREW, 4-40 x 1/4 PAN HEAD ..... PHIL	4	6-2/29		

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 3 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . SUPPORT, POST	2	6-2/30	06540	8530-A-0832
2	. . WASHER, FLAT, NO. 6	6	6-2/31		
3	. . WASHER, FLAT, NO. 8	2	6-2/32		
4	. . WASHER, FLAT, NO. 4	4	6-2/33		
5	. . WASHER, INSIDE STAR LOCK, ... NO. 4	4	6-2/34		
6	. . WASHER, INSIDE STAR LOCK, ... NO. 6	8	6-2/35		
7	. . WASHER, INSIDE STAR LOCK, ... NO. 8	2	6-2/36		
8	. . UNIT ASSY, IEEE 488 ..... INTERFACE	A/R	6-2/37,6-11	14028	552114
9	. . UNIT ASSY, RS-232C ..... INTERFACE	A/R	6-2/38,6-12	14028	552115
10	. . RACK MOUNT ADAPTER ASSY	A/R	6-2/39*	14028	552116
11	. FRONT PANEL ASSY	REF	6-2/1,6-3	14028	552100-2000
12	. . KEYBOARD, PCB ASSY	1	6-3/1		3027
13	. . FRONT PANEL DISPLAY BOARD ASSY .	1	6-3/2,6-4	14028	552100-2100
14	. . STUD, 4-40	6		05394	KFH-440-12
15	. . SPACER, NYLON	6	6-3/3	83330	4018
16	. . SWITCH, POWER	1	6-3/4		3088

*NOT ILLUSTRATED

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 4 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, VAR, 10K ±0.5%	1	6-3/5	19477	MR22-B14
2	. . CONNECTOR, BNC	4	6-3/6	96918	KC79-35
3	. . KNOB	1	6-3/7	86797	RB-67-1-DC-M
4	. . SPACER, NYLON	4	6-3/8	91833	3156
5	. . METER, MOVING COIL	1	6-3/9	32171	01-130-001-REV A
6	. . LUG, SOLDER, BNC	4	6-3/10		3105
7	. . SCREW, 2-56 x 5/8 PAN HEAD ..... PHIL	2	6-3/11		
8	. . SCREW, 4 x 1/4 SHEETMETAL ..... THREAD	2	6-3/12		
9	. . NUT, NO. 4	6	6-3/13		
10	. . WASHER, FLAT, NYLON, NO. 2	2	6-3/14		
11	. . NUT, NO. 2	2	6-3/15		
12	. . WASHER, INSIDE STAR LOCK, ... NO. 2	2	6-3/16		
13	. . WASHER, FIBER	2	6-3/17	06540	2265-F-443
14	. FRONT PANEL DISPLAY BOARD ..... ASSY	REF	6-3/2,6-4	14028	552100-2100
15	. . RES, 330 OHM ±5%, 1/4 W	8	6-4/R1,R4, R5,R6, R26-R29	24546	C4-331J
16	. . RES, 5.1K ±5%, 1/4 W	3	R2,R8,R14	24546	C4-512J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 5 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 12K ±5%, 1/4 W	3	R3,R9,R15	24546	C4-123J
2	. . RES, 10K ±5%, 1/4 W	9	R7,R10,R12, R17-R22	24546	C4-103J
		REF	R30,R31		
3	. . RES, 62K ±5%, 1/4 W	2	R11,R13	24546	C4-623J
4	. . RES, 2K ±5%, 1/4 W	1	R16	24546	C4-202J
5	. . RESISTOR NETWORK, 330 OHM	1	RN1	46711	750-81-R330
6	. . CAP, 47uF +100%, -10%, ... 16 V	3	C1,C6,C11	A000B	711-47-16
7	. . CAP, 22uF ±20%, 16 V	3	C2,C7,C10	14433	TAG20-22/16-20
8	. . CAP, 220uF +100%, -10%, ... 10 V	1	C3	A000B	711-220-10
9	. . CAP, 39pF ±5%, 500 V	1	C4	72136	CM05/DM15
10	. . CAP, 1uF ±20%, 35 V	1	C5	14433	TAG20-1/35-20
11	. . DIODE, SWITCHING	5	CR1-CR5	07263	1N4148
12	. . DIODE, LED	48	CR6-CR53		3101
13	. . TRANS, PNP	2	Q1,Q3	04713	2N3906
14	. . TRANS, PNP, POWER	2	Q2,Q5	04713	MJE700
15	. . TRANS, NPN	1	Q4	04713	2N3904
		REF	Q7		
16	. . INT CKT, TTL	3	U1,U11,U13	01295	SN74LS145 (LS ONLY)

Table 6-2. Parts List for the IMA 3000 Tape Motion Analyzer (Sheet 6 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, C-MOS	4	U2,U3,U8,U12	04713	14015
2	. . INT CKT, TTL	1	U4	01295	SN74LS139 (LS ONLY)
3	. . INT CKT, C-MOS	1	U5	04713	14051
4	. . INT CKT, TTL	1	U6	32293	ICM7226AIJL
5	. . INT CKT, TTL	2	U7,U10	01295	SN74LS05 (LS ONLY)
6	. . INT CKT, TTL	1	U9	01295	SN74LS04 (LS ONLY)
7	. . DISPLAY, SEVEN SEGMENT	5	D1-D5	72699	MAN4710
8	. . SOCKET DISPLAY	5	DS1-DS5	51167	CA-14SE-103WW
9	. . SOCKET, IC, 40 PIN	1	REF U6	01295	C8840-01
10	. . CONNECTOR, 10 PIN, DUAL	1	J1	08261	800-591
11	. . CONNECTOR, 20 PIN, DUAL	1	J2	08261	800-586
12	. . LED MOUNTS, NYLON	48	CR6-CR53	32559	907-355
13	. . CABLE	1			3072-4C & B
14	. . TEST POINT	5	TP1-TP5	71279	T29
15	. REAR PANEL ASSY	REF	6-2/2,6-5	14028	552100-3000
16	. . PANEL, REAR	1	6-5/1		3031
17	. . COVER PLATE, REAR PANEL	1	6-5/2		3053
18	. . TRANSFORMER	1	6-5/3		3052
19	. . SWITCH, AC LINE	1	6-5/4	82389	46206LFR

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 7 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . FUSE HOLDER	1	6-5/5	75915	3486-7-1
2	. . FUSE	1	6-5/6	75915	3AG 313001
3	. . AC LINE CORD W/GND	1	6-5/7	16428	17239
4	. . CORD HOLDER, AC LINE	1 PR	6-5/8	21604	PP-40055
5	. . BUSHING, STRAIN RELIEF	1	6-5/9	83330	939
6	. . TRANSISTOR, NPN, POWER	1	6-5/10	04713	MJE800T
7	. . PAD, INSULATOR	1	6-5/11	A000B	3223-07FR-54
8	. . CONNECTOR, BNC	4	6-5/12	02660	31-10
9	. . SCREW, 6-32 x 3/8 PAN HEAD ..... PHIL	4	6-5/13		
10	. . SCREW, 4-40 x 3/8 FLAT HEAD .... PHIL, BLACK OXIDE	1	6-5/14		
11	. . SCREW, 8-32 x 1-1/2 PAN HEAD ... PHIL	4	6-5/15		
12	. . SCREW, 8-32 x 1/2 FLAT HEAD .... PHIL, BLACK OXIDE	4	6-5/16		
13	. . SCREW, 6-32 x 3/8 FLAT HEAD .... PHIL, BLACK OXIDE	2	6-5/17		
14	. . WASHER, INSIDE STAR LOCK, ... NO. 4	1	6-5/18		
15	. . WASHER, INSIDE STAR LOCK, ... NO. 6	5	6-5/19		
16	. . WASHER, INSIDE STAR LOCK, ... NO. 8	3	6-5/20		

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 8 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . LUG, SOLDER, NO. 6	1	6-5/21		
2	. . LUG, SOLDER, NO. 8	3	6-5/22		
3	. . WASHER, FLAT, NO. 4	1	6-5/23		
4	. . WASHER, BLACK FIBER, NO. 8	4	6-5/24	83330	2163
5	. . WASHER, FLAT, NO. 8	4	6-5/25		
6	. . WASHER, BLACK FIBER, NO. 6	4	6-5/26	83330	2160
7	. . NUT, NO. 8	4	6-5/27		
8	. . NUT, NO. 6	6	6-5/28		
9	. . NUT, NO. 4	1	6-5/29		
10	. . SHOULDER WASHER, NYLON, NO. 4	1	6-5/30	04713	B51547F015
11	. POWER SUPPLY UNIT ASSY, RIGHT SIDE PLATE	REF	6-2/3	14028	552100-4000
12	. . POWER SUPPLY ASSY	1	6-2/40,6-6	14028	552100-4100
13	. . HEAT SINK BLOCK	1	6-2/41		3056
14	. . PLATE, RIGHT SIDE MTG	1	6-2/42		3028
15	. . VOLTAGE REGULATOR, PLUS	2	6-2/43	04713	MC7805CT
16	. . VOLTAGE REGULATOR, MINUS	2	6-2/44	04713	MC7905CT
17	. . STANDOFF, SELF-CLINCHING	5	6-2/45	05394	SOS-6440-16
18	. . SCREW, 4-40 x 3/8 PAN HEAD PHIL	5	6-2/46		
19	. . SCREW, 4-40 x 1/4 PAN HEAD PHIL	6	6-2/47		

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 9 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . SCREW, 6-32 x 3/4 FLAT HEAD .... PHIL, BLACK OXIDE	2	6-2/48		
2	. . SHOULDER WASHER, NYLON	4	6-2/49	04713	B51547F615
3	. . PAD, INSULATOR	4	6-2/50	A000B	3223-07FR-54
4	. . WASHER, INSIDE STAR LOCK, ... NO. 4	2	6-2/51		
5	. POWER SUPPLY ASSY	REF	6-2/40,6-6	14028	552100-4100
6	. . RES, 0.2 OHM ±1%, 1/4 W	1	6-6/R1	91637	RS-1A
7	. . RES, 3.92K ±1%, 1/4 W	2	R2,R7	80031	RN55D
8	. . RES, 316 OHM ±1%, 1/4 W	1	R3	80031	RN55D
9	. . RES, 33K ±5%, 1/4 W	1	R4	24546	C4-333J
10	. . RES, 1.30K ±1%, 1/4 W	1	R5	80031	RN55D
11	. . RES, 330 OHM ±5%, 1/4 W	4	R6,R13,R14, R19	24546	C4-331J
12	. . RES, 10.0K ±1%, 1/4 W	2	R9,R18	80031	RN55D
13	. . RES, 14.0K ±1%, 1/4 W	1	R10	80031	RN55D
14	. . RES, 22.6K ±1%, 1/4 W	4	R11,R12,R15, R16	80031	RN55D
15	. . RES, 2.00K ±1%, 1/4 W	1	R17	80031	RN55D
16	. . RES, 1K ±5%, 1/4 W	2	R20,R22	24546	C4-102J
17	. . RES, 33 OHM ±5%, 1/4 W	1	R21	24546	C4-330J
18	. . RES, VAR, 1K ±20%, 1/4 W	1	R8	80294	3386W-1-102

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 10 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CAP, 15,000uF ±20%, 16 V	1	C1	55680	TNBIC 153 MDA
2	. . CAP, 3,300uF ±20%, 25 V	2	C2,C3	55680	ULBIE 332M
3	. . CAP, 1uF ±20%, 35 V	1	C4	15238	TAG20-1/35-20
4	. . CAP, 0.001uF ±10%, 63 V	3	C5,C7,C8	53673	IR67102K
5	. . CAP, 220uF +100%, -10%, 10 V	1	C6	55680	ULBIA221M
6	. . CAP, 47uF ±20%, 16 V	4	C9-C12	55680	ULBIC470M
7	. . CAP, 0.1uF ±10%, 63 V	1	C13	53673	IR67104K
8	. . DIODE, RECT, 6 AMP, 50 V	4	CR1-CR4	04713	MR750
9	. . DIODE, RECT, 3 AMP, 50 V	4	CR5-CR8	01002	A15F
10	. . DIODE, SWITCHING	2	CR9,CR10	07263	1N4148
11	. . DIODE, ZENER, 3.3 V 5%	2	CR11,CR12	07263	1N746A
12	. . DIODE, ZENER, 8.2 V 5%	2	CR13,CR14	07263	1N756A
13	. . DIODE, ZENER, 5.6 V 5%	1	CR15	07263	1N752A
14	. . DIODE, RECT, 1 AMP, 400 V	5	CR16-CR20	04713	1N4004
15	. . SILICON CONTROLLED RECT	1	SCR1	04713	MCR69-1
16	. . TRANS, POWER, NPN	REF	Q1	04713	MJE800T
17	. . VOLTAGE REGULATOR, PLUS	REF	VR1,VR2	04713	MC7805CT
18	. . VOLTAGE REGULATOR, MINUS	REF	VR3,VR4	04713	MC7905CT
19	. . INT CKT, LINEAR	1	U1	27014	LM723

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 11 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, LINEAR, QUAD	1	U2	27014	LM324
2	. . CONNECTOR, 6 PIN W/LOCK	1	J1	27264	09-72-2061
3	. . CONNECTOR, 8 PIN W/LOCK	2	J2,J3	27264	09-72-2081
4	. . CONNECTOR, 3 PIN W/LOCK	1	J4	27264	09-72-2031
5	. . SOCKET, TRANSISTOR, 3 PIN	4	J5-J8	27264	22-15-2036
6	. . SOCKET, TRANSISTOR, 3 PIN	1	CABLE FOR Q1	27264	22-01-2031
7	. . PIN, TRANSISTOR SOCKET	3	CABLE FOR Q1	27264	08-50-0114
8	. . TEST POINT	2	TPO,TP1	71279	T29
9	. MICROPROCESSOR/D-MOD UNIT ASSY ...	REF	6-2/4	14028	552100-5000
10	. . MICROPROCESSOR BOARD ASSY	1	6-2/52,6-7	14028	552100-7000
11	. . D-MOD BOARD ASSY	1	6-2/53,6-8	14028	552100-8000
12	. . MOUNTING PLATE, ... MIROPROCESSOR/D-MOD	1	6-2/54		3058
13	. . SHIELD, D-MOD	1	6-2/55		3065
14	. . HINGED STANDOFF	3	6-2/56	91833	358
15	. . STANDOFF, SELF-CLINCHING	13	6-2/57	05394	SOS-6440-6
16	. . STANDOFF, ROUND	2	6-2/58	83330	8775
17	. . SCREW, 4-40 x 1/4 PAN HEAD ..... PHIL	17	6-2/59		
18	. . WASHER, INSIDE STAR LOCK, ... NO. 4	4	6-2/60		

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 12 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . WASHER, INSIDE STAR LOCK, ... NO. 6	3	6-2/61		
2	. . NUT, NO. 6	3	6-2/62		
3	. . PROTECTIVE EDGE MOULDING, ... BLACK	A/R	6-2/63		3073
4	. . PROTECTIVE EDGE MOULDING	A/R	6-2/64	06915	SPGS-2
5	. . SUPPORT POST	2	6-2/65	06540	8532-A-0632
6	. . PHENOLIC STANDOFF	1	6-2/66	06540	8174-PH-0632
7	. MICROPROCESSOR BOARD ASSY	REF	6-2/52, 6-7	14028	552100-7000
8	. . RES, 2.2K ±5%, 1/4 W	11	6-7/R1-R3, R5-R7,R9, R10,R19, R21,R23	24546	C4-222J
9	. . RES, 20K ±5%, 1/4 W	1	R8	24546	C4-203J
10	. . RES, 470 OHM ±5%, 1/4 W	2	R11,R18	24546	C4-471J
11	. . RES, 1.5K OHM ±5%, 1/4 W	2	R12,R13	24546	C4-152J
12	. . RES, 1K ±5%, 1/4 W	9	R14,R17, R22, R24-R29	24546	C4-102J
13	. . RES, 10K ±5%, 1/4	1	R15	24546	C4-103J
14	. . RES, 390 OHM ±5%, 1/4 W	1	R16	24546	C4-391J
15	. . RESISTOR NETWORK, 10K	1	RN1	46711	750-101-R10K
16	. . RESISTOR NETWORK, 5.6K	2	RN2,RN3	80740	898-1-R5.6K

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 13 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CAP, 0.1uF ±10%, 63 V	22	C1-C3,C5, C7,C9-C11, C13,C16,C17, C19,C21-C24, C26-C31	53673	1R67104K
2	. . CAP, 0.001uF ±10%, 63 V	1	C4	53673	1R67102K
3	. . CAP, 47uF +100%, -10%, ... 16 V	1	C6	A000B	711-47-16
4	. . CAP, 100pF ±5%, 500 V	1	C8	72136	CM05/DM15
5	. . CAP, 22uF ±20%, 16 V	3	C14,C15, C20	15238	TAG020-22/16-20
6	. . CAP, 4.7uF ±20%, 35 V	1	C18	15238	TAG020-4.7/35-20
7	. . CAP, 10uF ±20%, 35 V	1	C25	15238	TAG020-10/35-20
8	. . CAP, 10pF ±5%, 500 V	1	C32	72136	CM05/DM15
9	. . CAP, 0.01uF ±10%, 500 V	1	C33	49956	CK05
10	. . CAP, VAR, 2-10 pF	1	C12	73445	C010KA/10E
11	. . DIODE, SWITCHING	1	CR1	07263	1N4148
12	. . INT CKT, TTL	3	U1,U8,U19	01295	74LS74 (LS ONLY)
13	. . INT CKT, TTL	1	U2	01295	74LS107 (LS ONLY)
14	. . INT CKT, TTL	1	U3	01295	74LS123 (LS ONLY)
15	. . INT CKT, TTL	1	U4	01295	74LS86 (LS ONLY)

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 14 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, TTL	2	U5,U13	01295	74LS00 (LS ONLY)
2	. . INT CKT, TTL	2	U6,U7	01295	74LS163 (LS ONLY)
3	. . INT CKT, TTL	1	U9	01295	74LS90 (LS ONLY)
4	. . INT CKT, TTL	1	U10	01295	74LS93 (LS ONLY)
5	. . INT CKT, TTL	1	U11	01295	74S04 (S ONLY)
6	. . INT CKT	1	U12	33297	8255
7	. . INT CKT, TTL	2	U14,U21	01295	74LS125 (LS ONLY)
8	. . INT CKT	1	U15	33297	8085A
9	. . INT CKT, TTL	2	U16,U20	01295	74LS04 (LS ONLY)
10	. . INT CKT, TTL	1	U17	01295	74LS138 (LS ONLY)
11	. . INT CKT	1	U18	33297	8155A
12	. . INT CKT, TTL	1	U22	01295	74LS30 (LS ONLY)
13	. . INT CKT, TTL	1	U23	01295	74LS373 (LS ONLY)
14	. . INT CKT, PROGRAMMED ROM	1 SET	U24-U26		3042

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 15 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . SOCKET, IC, 24 PIN	2	REF U24,U25	01295	C8824-01
2	. . SOCKET, IC, 40 PIN	3	REF U12,U15, U18	01295	C8840-01
3	. . CRYSTAL, 8 MHz	1	Y1		3134
4	. . CONNECTOR, 10 PIN	1	J1	08261	800-591
5	. . CONNECTOR, 34 PIN	1	J2	59730	609-3427
6	. . CONNECTOR, 20 PIN	4	J3-J6	59730	609-2027
7	. . CONNECTOR, TEST, 50 PIN	1	J7	08261	800-571
8	. . CONNECTOR, RT, 6 PIN	1	J8	27264	09-90-1061
9	. . TEST POINT	3	TP0-TP2	71279	T29
10	. . GROUND LUG, NO. 6	1			
11	. D-MOD BOARD ASSEMBLY	REF	6-2/53, 6-8	14028	552100-8000
12	. . RES, 1K ±5%, 1/4 W	7	6-8/R1,R47, R50,R56,R57, R59,R60,R90	24546	C4-102J
13	. . RES, 10K ±5%, 1/4 W	7	R2,R48,R54, R55,R70,R71, R84	24546	C4-103J
14	. . RES, 3.16K ±1%, 1/4 W	1	R3	80031	RN55D
15	. . RES, 4.02K ±1%, 1/4 W	1	R4	80031	RN55D
16	. . RES, 100K ±5%, 1/4 W	5	R5,R41,R75, R76,R80	24546	C4-104J
17	. . RES, 2.00K ±1%, 1/4 W	3	R6,R16,R18	80031	RN55D

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 16 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 825 OHM ±1%, 1/4 W	2	R7,R11	80031	RN55D
2	. . RES, 270 OHM ±5%, 1/4 W	7	R8,R9,R10, R23,R26, R37,R40	24546	C4-271J
3	. . RES, 2K ±5%, 1/4 W	2	R12,R72	24546	C4-202J
4	. . RES, 4.7K ±5%, 1/4 W	1	R13	24546	C4-472J
5	. . RES, 24K ±5%, 1/4 W	2	R14,R22	24546	C4-243J
6	. . RES, 5.1K ±5%, 1/4 W	6	R15,R53,R58, R57,R62,R91	24546	C4-512J
7	. . RES, 3.01K ±1%, 1/4 W	2	R20,R27	80031	RN55D
8	. . RES, 3.57K ±1%, 1/4 W	1	R21	80031	RN55D
9	. . RES, 6.98K ±1%, 1/4 W	1	R17	80031	RN55D
10	. . RES, 2.87K ±1%, 1/4 W	1	R24	80031	RN55D
11	. . RES, 2.55K ±1%, 1/4 W	1	R25	80031	RN55D
12	. . RES, 499 OHM ±1%, 1/4 W	3	R28,R29,R32	80031	RN55D
13	. . RES, 220 OHM ±5%, 1/4 W	5	R30,R31,R45, R46,R73	24546	C4-221J
14	. . RES, 9.09K ±1%, 1/4 W	1	R33	80031	RN55D
15	. . RES, 12.1K ±1%, 1/4 W	1	R34	80031	RN55D
16	. . RES, 30K ±5%, 1/4 W	1	R35	24546	C4-303J
17	. . RES, 620K ±5%, 1/4 W	1	R36	24546	C4-624J
18	. . RES, 7.50K ±1%, 1/4 W	1	R38	80031	RN55D

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 17 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 1.00K ±1%, 1/4 W	2	R39,R67	80031	RN55D
2	. . RES, 470 OHM ±5%, 1/4 W	1	R42	24546	C4-471J
3	. . RES, 56 OHM ±5%, 1/4 W	2	R43,R44	24546	C4-560J
4	. . RES, 3.3M ±5%, 1/4 W	1	R64	24546	C4-335J
5	. . RES, 300 OHM ±5%, 1/4 W	3	R49,R52,R66	24546	C4-301J
6	. . RES, 15K ±5%, 1/4 W	2	R51,R69	24546	C4-153J
7	. . RES, 510 OHM ±5%, 1/4 W	3	R61,R86,R96	24546	C4-511J
8	. . RES, 10.7K ±1%, 1/4 W	1	R63	80031	RN55D
9	. . RES, 5.11K ±1%, 1/4 W	1	R68	80031	RN55D
10	. . RES, 100 OHM ±5%, 1/4 W	1	R74	24546	C4-101J
11	. . RES, 51K ±5%, 1/4 W	3	R92-R94	24546	C4-513J
12	. . RES, 6.2K ±5%, 1/4 W	2	R77,R78	24546	C4-622J
13	. . RES, 20K ±5%, 1/4 W	4	R65,R79, R81,R83	24546	C4-203J
14	. . RES, VAR, 2K	1	R19	80294	3299W
15	. . RES, VAR, 1K	1	R85	80294	3299W
16	. . RES, 270K ±5%, 1/4 W	1	R82	24546	C4-274J
17	. . RES, 3K ±5%, 1/4 W	1	R87	24546	C4-302J
18	. . RES, 2.2K ±5%, 1/4 W	1	R89	24546	C4-222J
19	. . RES, VAR, 5K	1	R95	80294	3299W
20	. . RES, 10K ±1%, 1/4 W	1	R88	80031	RN55D

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 18 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES NETWORK, CUSTOM	3	RN1,RN2, RN4		3050-A,C,B
2	. . RES NETWORK, 3.3K	1	RN3	46711	CTS-750-61-R3.3K
3	. . THERMISTOR, 3K	1	RT1	15801	KA33J1
4	. . CAP, 0.033uF ±10%, 63 V	3	C1,C3,C5	53673	1R67333K
5	. . CAP, 0.1uF ±10%, 63 V	13	C2,C8, C13-C15, C17,C19,C21, C49,C56,C57, C61,C71	53673	1R67104K
6	. . CAP, 0.22uF ±10%, 63 V	1	C4	53673	1R87224K
7	. . CAP, 0.068uF ±10%, 63 V	1	C6	53673	1R67683K
8	. . CAP, 0.001uF ±10%, 63 V	2	C7,C68	53673	1R67102K
9	. . CAP, 0.0068uF ±10%, 63 V	2	C9,C54	53673	1R67682K
10	. . CAP, 0.0022uF ±10%, 63 V	3	C10,C20,C51	53673	1R67222K
11	. . CAP, 0.015uF ±10%, 63 V	1	C11	53673	1R67153K
12	. . CAP, 0.022uF ±10%, 63 V	1	C12	53673	1R67223K
13	. . CAP, 0.047uF ±10%, 63 V	2	C16,C58	53673	1R67473K
14	. . CAP, 0.47uF ±10%, 63 V	1	C18	53673	1R87474K
15	. . CAP, 0.0015uF ±10%, 63 V	4	C22,C24, C31,C33	53673	1R67152K
16	. . CAP, 0.0047uF ±10%, 63 V	2	C23,C43	53673	1R67472K

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 19 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CAP, 0.01uF ±10%, 63 V	4	C25,C55, C59,C69	53673	1R67103K
2	. . CAP, TANTALUM, 22uF ±20%, 16 V .	10	C26,C36, C37,C42, C48,C50, C60,C62, C63,C66	15238	TAG20-22/16-20
3	. . CAP, 47uF ±20%, 16 V	5	C27-C30, C40	55680	ULB1C470M
4	. . CAP, TANTALUM, 15uF ±20%, 20 V .	2	C35,C47	14433	TAG20-15/20-20
5	. . CAP, 0.68uF ±5%, 100 V	1	C46	56289	451P684X5100J
6	. . CAP, 200pF ±5%, 500 V	1	C53	72136	CM05/DM15
7	. . CAP, 0.0033uF ±10%, 63 V	1	C65	53673	1R67332K
8	. . CAP, 470pF ±5%, 500 V	1	C34	72136	CM05/DM15
9	. . CAP, 5-60pF, VAR	1	C41	73445	C010MA/60E
10	. . CAP, 150pF ±5%, 500 V	1	C39	72136	CM05/DM15
11	. . CAP, 750pF ±5%, 500 V	1	C52	72136	CM05/DM15
12	. . CAP, 4.7uF ±20%, 35 V	1	C67	15238	TAG20-4.7/ 35-20
13	. . CAP, 100uF ±20%, 3 V	1	C70	15238	TAG20-100/ 3-20
14	. . CAP, SELECT IN TEST	2	C45,C64		
15	. . DIODE, ZENER, 5.6 V	2	CR1,CR2	07263	1N752A
16	. . DIODE, SWITCHING	8	CR3-CR7, CR13-CR15	07263	1N4148

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 20 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . DIODE, ZENER, 8.2 V	5	CR8-CR12	07263	1N756A
2	. . DIODE NETWORK	1	CRN1		3048 C & B
3	. . TRANSISTOR, PNP	3	Q1,Q2,Q15	04713	2N3906
4	. . TRANSISTOR, NPN	7	Q3-Q5, Q11-Q14	04713	2N3904
5	. . TRANSISTOR, FET, N CHANNEL	1	Q6	04713	2N5485
6	. . TRANSISTOR, PNP	2	Q7,Q10	27014	2N5910
7	. . TRANSISTOR, FET, N CHANNEL	1	Q8	04713	2N4859
8	. . TRANSISTOR, NPN	1	Q9	04713	MPS2369
9	. . INT CKT, LINEAR, QUAD	1	U1	27014	LM339
10	. . INT CKT, C-MOS	5	U2,U9, U11,U23, U25	04713	14051
11	. . INT CKT, REGULATOR, SIT	1	U3	27014	LM723
12	. . INT CKT, TRANS, ARRAY, SIT	3	U4,U8,U24	27014	LM3046 (NATIONAL ONLY)
13	. . INT CKT, C-MOS	2	U5,U10	04713	14053
14	. . INT CKT, LINEAR, QUAD	3	U6,U17, U18	01295	TL084
15	. . INT CKT, TRANS, ARRAY, SIT	1	U7	04713	MPQ3906
16	. . INT CKT, C-MOS	2	U12,U21	04713	14013
17	. . INT CKT, C-MOS	2	U13,U26	04713	14528 (MOTOROLA ONLY)

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 21 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, C-MOS	3	U14,U19,U20	04713	14016
2	. . INT CKT, C-MOS	2	U16,U22	04713	14015
3	. . INT CKT, C-MOS	1	U15	04713	14070
4	. . SOCKET, IC, 14 PIN	4	REF U3,U4, U7,U8	01295	C8814-01
5	. . CONNECTOR, HEADER, 20 PIN	1	J1	59730	609-2027
6	. . TEST POINT	22	TP0-TP21	71279	T29
7	. INTERCONNECT BOARD ASSY	REF	6-2/5,6-9	14028	552100-6000
8	. . RES, 620 OHM ±5%, 1/4 W	3	R3,R4,R113	24546	C4-621J
9	. . RES, 1K ±5%, 1/4 W	15	R5,R8,R21, R24,R29,R32, R81,R91, R116,R138, R142,R152, R153,R176, R178	24546	C4-102J
10	. . RES, 3K ±5%, 1/4 W	7	R6,R7,R9, R10,R155, R158,R160	24546	C4-302J
11	. . RES, 1M ±5%, 1/4 W	4	R19,R26,R27, R34	24546	C4-105J
12	. . RES, 100K ±5%, 1/4 W	10	R20,R25,R28, R33,R47-R50, R77,R145	24546	C4-104J
13	. . RES, 4.7K ±5%, 1/4 W	4	R22,R23,R30, R31	24546	C4-472J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 22 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 51K ±5%, 1/4 W	1	R35	24546	C4-513J
2	. . RES, 4.99K ±1%, 1/4 W	2	R36,R41	80031	RN55D
3	. . RES, 100K ±1%, 1/4 W	1	R37	80031	RN55D
4	. . RES, 11.0K ±1%, 1/4 W	1	R38	80031	RN55D
5	. . RES, 10.0K ±1%, 1/4 W	21	R39,R40,R65, R68,R69,R76, R78-R80,R86-R88,R90,R97, R99,R117, R119,R120, R122,R150, R151	80031	RN55D
6	. . RES, 15.0K ±1%, 1/4 W	1	R42	80031	RN55D
7	. . RES, 316 OHM ±1%, 1/4 W	3	R43,R82,R92	80031	RN55D
8	. . RES, 28.7K ±1%, 1/4 W	2	R44,R56	80031	RN55D
9	. . RES, 287K ±1%, 1/4 W	2	R45,R55	80031	RN55D
10	. . RES, 2.67K ±1%, 1/4 W	2	R46,R57	80031	RN55D
11	. . RES, 3.01K ±1%, 1/4 W	3	R51,R52,R144	80031	RN55D
12	. . RES, 1.50K ±1%, 1/4 W	3	R53,R108, R134	80031	RN55D
13	. . RES, 200K ±5%, 1/4 W	1	R54	24546	C4-204J
14	. . RES, 3.6K ±5%, 1/4 W	5	R58,R59, R61-R63	24546	C4-362J
15	. . RES, 2K ±5%, 1/4 W	1	R60	24546	C4-202J
16	. . RES, 3.3M ±5%, 1/4 W.....	3	R64,R66,R112	24546	C4-335J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 23 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 20.0K ±1%, 1/4 W	5	R67,R71, R139-R141	80031	RN55D
2	. . RES, 12.1K ±1%, 1/4 W	1	R70	80031	RN55D
3	. . RES, 10K ±5%, 1/4 W	2	R72,R73	24546	C4-103J
4	. . RES, 7.50K ±1%, 1/4 W	1	R75	80031	RN55D
5	. . RES, 681 OHM ±1%, 1/4 W	2	R83,R93	80031	RN55D
6	. . RES, 2.15K ±1%, 1/4 W	2	R84,R94	80031	RN55D
7	. . RES, 6.81K ±1%, 1/4 W	2	R85,R95	80031	RN55D
8	. . RES, 2.61K ±1%, 1/4 W	1	R89	80031	RN55D
9	. . RES, 34.0K ±1%, 1/4 W	1	R96	80031	RN55D
10	. . RES, 57.6K ±1%, 1/4 W	1	R98	80031	RN55D
11	. . RES, 20K ±5%, 1/4 W	1	R100	24546	C4-102J
12	. . RES, 2.2M ±5%, 1/4 W	6	R101,R102, R123-R126	24546	C4-225J
13	. . RES, OPTIONAL, NOT USED	REF	R103,R105, R107,R129, R131,R132		
14	. . RES, 162K ±1%, 1/4 W	2	R104,R130	80031	RN55D
15	. . RES, 24.9K ±1%, 1/4 W	2	R106,R133	80031	RN55D
16	. . RES, 300 OHM ±5%, 1/4 W	4	R109,R135, R159,R161	24546	C4-301J
17	. . RES, 100 OHM ±5%, 1/4 W	4	R110,R136, R175,R177	24546	C4-101J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 24 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 1.00M ±1%, 1/4 W	2	R111,R137	80031	RN55D
2	. . RES, 4.64K ±1%, 1/4 W	1	R114	80031	RN55D
3	. . RES, 8.45K ±1%, 1/4 W	1	R115	80031	RN55D
4	. . RES, 14.0K ±1%, 1/4 W	1	R118	80031	RN55D
5	. . RES, 38.3K ±1%, 1/4 W	1	R121	80031	RN55D
6	. . RES, 2.2K ±5%, 1/4 W	1	R127	24546	C4-222J
7	. . RES, 430 OHM ±5%, 1/4 W	1	R128	24546	C4-431J
8	. . RES, 1.00K ±1%, 1/4 W	1	R143	80031	RN55D
9	. . RES, 1.8K ±5%, 1/4 W	1	R146	24546	C4-182J
10	. . RES, 47 OHM ±5%, 1/4 W	1	R147	24546	C4-470J
11	. . RES, 510 OHM ±5%, 1/4 W	1	R148	24546	C4-511J
12	. . RES, 5.1K ±5%, 1/4 W	1	R149	24546	C4-512J
13	. . RES, 1.5K ±5%, 1/4 W	1	R154	24546	C4-152J
14	. . RES, 39 OHM ±5%, 1/4 W	1	R164	24546	C4-390J
15	. . RES, 33 OHM ±5%, 1/2 W	2	R165,R166	24546	RCR20G330JS
16	. . RES, VAR, 10K ±20%, 1/4 W	3	R156,R173, R174	80294	3299W
17	. . RES, 10 OHM ±5%, 1/4 W	2	R162,R163	24546	C4-100J
18	. . RES, VAR, 2K ±20%, 1/4 W	3	R167,R168, R170	80294	3299W
19	. . RES, VAR, 1K ±20%, 1/4 W	1	R169	80294	3299W
20	. . RES, VAR, 5K ±20%, 1/4 W	1	R171	80294	3299W

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 25 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, VAR, 500 OHM ±20%, 1/4 W ..	1	R172	80294	3299W
2	. . RES, VAR, 10K	REF	R175	19477	MR22-1314
3	. . RESISTOR NETWORK, PRECISION	4	RN1-RN4		3050-A,C & B
4	. . THERMISTOR, 1K OHM	1	RT1	15801	K13J1
5	. . CAP, TANTALUM, 10uF ±20%, 35 V .	8	C1-C4,C6-C9	14433	TAG20-10/35-20
6	. . CAP, 0.1uF ±10%, 250 V	4	C10-C13	73445	C280AEP100K
7	. . CAP, 0.1uF ±1%, 63 V SIT	2	C14,C17 (Matched Set)	53673	1R67104K
8	. . CAP, 91pF ±1%, 500 V SIT	2	C15,C18 (Matched Set)	72136	CM05/DM15
9	. . CAP, 910pF ±1%, 500 V SIT	2	C16,C19 (Matched Set)	72136	CM05/DM15
10	. . CAP, 0.01uF ±10%, 63 V	1	C20	53673	1R67103K
11	. . CAP, 47uF ±20%, 16 V	8	C21-C24,C48, C49,C54,C56	55680	ULB1C470M
12	. . CAP, 0.47uF ±10%, 63 V	1	C25	53673	1R87474K
13	. . CAP, 0.001uF ±10%, 63 V	2	C26,C28	53673	1R67102K
14	. . CAP, 0.0015uF ±10%, 63 V	1	C27	53673	1R67152K
15	. . CAP, 0.1uF ±10%, 63 V	2	C29,C37	53673	1R67104K
16	. . CAP, 82pF ±5%, 500 V.	1	C30	72136	CM05/DM15
17	. . CAP, 0.68uF ±5%, 100 V	3	C31,C34,C46	56289	451P684X5100J
18	. . CAP, (820pF TO 0.001uF) ..... (PART OF MATCHED SET)	4	C32,C35,C39, C40		3123

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 26 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CAP, 0.0022uF ±1%, 63 V SIT .... (PART OF MATCHED SET)	4	C33,C36, C38,C41	53673	1R67222K
2	. . CAP, 36pF ±5%, 500 V	1	C42	72136	CM05/DM15
3	. . CAP, 0.022uF ±10%, 63 V	1	C43	53673	1R67223K
4	. . CAP, 0.015uF ±10%, 63 V	1	C44	53673	1R67153K
5	. . CAP, TANTALUM, 15uF ±1%, ... 20 V SIT	2	C45,C47	14433	TAG20-15/20-20
6	. . CAP, 22uF ±20%, 35 V	4	C50-C53	55680	ULB1V220M
7	. . CAP, 0.01uF ±10%, 500 V	1	C55	49956	CK05
8	. . DIODE, SWITCHING	27	CR1-CR12, CR14-CR28	07263	1N4148
9	. . TRANS, PNP	5	Q1,Q2,Q9, Q11,Q14	04713	2N3906
10	. . TRANS, FET, N-CHANNEL	4	Q3-Q6	04713	2N5485
11	. . TRANS, NPN	6	Q8,Q10,Q15, Q16-Q18	04713	2N3904
12	. . TRANS, NPN	1	Q12	04713	MPS2369
13	. . TRANS, PNP	1	Q13	07263	2N5910
14	. . VOLTAGE REGULATOR	1	VR1	27014	LM336Z
15	. . INT CKT, DIGITAL, CMOS	5	U1,U3,U26, U45,U49	04713	14016
16	. . INT CKT, DIGITAL, CMOS	2	U2,U35	04713	14049
17	. . INT CKT, DIGITAL, CMOS	7	U4,U9,U20, U22,U29,U31, U34	04713	14052

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 27 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, DIGITAL, CMOS	5	U5,U8, U10,U33, U42	04713	14015
2	. . INT CKT, DIGITAL, CMOS	1	U6	04713	14025
3	. . INT CKT, DIGITAL, CMOS	8	U7,U19, U36-U39, U44,U55	04713	14051
4	. . INT CKT, DIGITAL, CMOS	2	U11,U21	27014	14066B (NATIOANAL ONLY)
5	. . INT CKT, DIGITAL, CMOS	1	U12	04713	14001
6	. . INT CKT, DIGITAL, CMOS	1	U13	04713	14094B
7	. . INT CKT, DIGITAL, CMOS	1	U14	04713	14028
8	. . INT CKT, DIGITAL, CMOS	1	U15	04713	14027
9	. . INT CKT, DIGITAL, CMOS	2	U16,U52	04713	14011
10	. . INT CKT, LINEAR, QUAD	7	U17,U23,U25, U28,U30,U48, U51	01295	TL084
11	. . INT CKT, D/A CONVERTER	1	U18	27014	DAC0808
12	. . INT CKT, LINEAR	2	U24,U56	27014	LF356
13	. . INT CKT, DIGITAL, CMOS	1	U27	04713	14046
14	. . INT CKT, DIGITAL, CMOS	1	U32	04713	14518
15	. . INT CKT, DIGITAL, CMOS	1	U40	04713	14053
16	. . INT CKT, DIGITAL, CMOS	1	U41	04713	14528 (MOTOROLA ONLY)
17	. . INT CKT, A/D CONVERTER	1	U43	27014	ADC0804

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 28 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . INT CKT, LINEAR, QUAD	2	U46,U50	27014	LM339
2	. . INT CKT	1	U47	01295	TL082
3	. . INT CKT, DIGITAL, CMOS	1	U53	04713	14040
4	. . INT CKT, DIGITAL, CMOS	1	U54	04713	14013
5	. . INT CKT, LINEAR, DUAL	1	U57	27014	LM358
6	. . SOCKET, IC, 16 PIN	3	REF U18, U27,U41	01295	C8816-01
7	. . SOCKET, IC, 20 PIN	1	REF U43	01295	C8820-01
8	. . CONNECTOR, 25 PIN	2	J1,J2	22526	65516-136
9	. . CONNECTOR, 10 PIN ..... (HEADER W/PINS)	2	J3,J8	59730	609-1027 (BLUE ANSLEY ONLY)
10	. . CONNECTOR, 6 PIN	1	J4	27264	09-72-2061
11	. . CONNECTOR, 20 PIN ..... (HEADER W/PINS)	3	J5,J6,J7	59730	609-2027 (BLUE ANSLEY ONLY)
12	. . BUS BAR	1	BB1	31745	M834 11.10
13	. . TEST POINT	26	TP0-TP25	82893	T29
14	. INPUT CHANNEL CONDITIONER ASSY ...	REF	6-2/8,6-10	14028	552100-9000
15	. . RES, 300 OHM ±5%, 1/4 W	3	6-10/R1,R12, R65	24546	C4-301J
16	. . RES, 2.00K ±1%, 1/4 W	2	R2,R3	80031	RN55D
17	. . RES, 3.9K ±5%, 1/4 W	1	R4	24546	C4-392J
18	. . RES, 27K ±5%, 1/4 W	1	R5	24546	C4-273J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 29 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 10K ±5%, 1/4 W	6	R6,R31,R34, R38,R46,R52	24546	C4-103J
2	. . RES, 100K ±5%, 1/4 W	2	R7,R8	24546	C4-104J
3	. . RES, 3.3K ±5%, 1/4 W	3	R9,R10,R66	24546	C4-332J
4	. . RES, 681 OHM ±1%, 1/4 W	1	R11	80031	RN55D
5	. . RES, 5.1K ±5%, 1/4 W	4	R13,R25,R26, R35	24546	C4-512J
6	. . RES, 1K ±5%, 1/4 W	10	R14,R17,R19, R48,R49, R60-R64	24546	C4-102J
7	. . RES, 1M ±5%, 1/4 W	3	R15,R16,R18	24546	C4-105J
8	. . RES, SIT ±5%, 1/4 W	1	R20	24546	
9	. . RES, 4.7K ±5%, 1/4 W	2	R21,R22	24546	C4-472J
10	. . RES, SIT ±5%, 1/4 W	1	R23	24546	
11	. . RES, 2.2K ±5%, 1/4 W	1	R24	24546	C4-222J
12	. . RES, 750 OHM ±5%, 1/4 W	1	R27	24546	C4-751J
13	. . RES, 510K ±5%, 1/4 W	1	R28	24546	C4-514J
14	. . RES, 12K ±5%, 1/4 W	1	R29	24546	C4-123J
15	. . RES, 3K ±5%, 1/4 W	1	R30	24546	C4-302J
16	. . RES, 100 OHM ±5%, 1/4 W	6	R32,R33,R37, R39,R47,R51	24546	C4-101J
17	. . RES, 180 OHM ±5%, 1/4 W	1	R36	24546	C4-181J
18	. . RES, 360 OHM ±5%, 1/4 W	1	R40	24546	C4-361J

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 30 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . RES, 10.0K ±1%, 1/4 W	6	R41-R43, R53-R55	80031	RN55D
2	. . RES, 3.57K ±1%, 1/4 W	1	R44	80031	RN55D
3	. . RES, 1.78K ±1%, 1/4 W	1	R45	80031	RN55D
4	. . RES, 1.5K ±5%, 1/4 W	1	R50	24546	C4-152J
5	. . RES, 5.11K ±1%, 1/4 W	1	R56	80031	RN55D
6	. . RES, 1.00K ±1%, 1/4 W	1	R57	80031	RN55D
7	. . RES, 75K ±5%, 1/4 W	1	R67	24546	C4-753J
8	. . RES, VAR, 5K ±20%, 1/2 W	1	R58	80294	3386W-1-502
9	. . RESISTOR NETWORK, PRECISION	5	RN1-RN5		3050-A,C & B
10	. . CAP, 36pF ±5%, 500 V	1	C1	72136	CM05/DM15
11	. . CAP, 510pF ±5%, 500 V	1	C2	72136	CM05/DM15
12	. . CAP, 120pF ±5%, 500 V	1	C3	72136	CM05/DM15
13	. . CAP, 0.1uF ±20%, 63 V	12	C4,C10-C13, C19-C21, C30-C33	53673	1R67104K
14	. . CAP, 2pF ±5%, 500 V	1	C5	72136	CM05/DM15
15	. . CAP, 220pF ±5%, 500 V	2	C6,C7	72136	CM05/DM15
16	. . CAP, 1uF ±20%, 35 V	2	C8,C9	14433	TAG20-1/35-20
17	. . CAP, 47uF ±20%, 16 V	4	C14-C17	55680	ULB1C470M
18	. . CAP, 15uF ±20%, 20 V	5	C18, C22-C25	14433	TAG20-15/20-20
19	. . CAP, 430pF ±5%, 500 V	1	C26	72136	CM05/DM15

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 31 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . CAP, 470pF ±5%, 500 V	2	C27,C36	72136	CM05/DM15
2	. . CAP, 39pF ±5%, 500 V	1	C28	72136	CM05/DM15
3	. . CAP, 240pF ±5%, 500 V	2	C34,C35	72136	CM05/DM15
4	. . CAP, 30pF ±5%, 500 V	1	C37	72136	CM05/DM15
5	. . DIODE, SWITCHING	12	CR1-CR12	07263	1N4148
6	. . TRANS, NPN	3	Q1,Q2,Q8	04713	2N3904
7	. . TRANS, PNP, DARLINGTON	1	Q3	04713	MPS A64
8	. . TRANS, PNP	5	Q4-Q7,Q9	04713	2N3906
9	. . INT CKT, LINEAR	1	U1	27014	LF357
10	. . INT CKT, LINEAR, DUAL	1	U2	27014	LM358
11	. . INT CKT, LINEAR	1	U3	02735	CA3054
12	. . INT CKT, LINEAR, QUAD	2	U4,U8	01295	TL084
13	. . INT CKT, C-MOS	5	U5,U6, U9-U11	04713	14051
14	. . INT CKT, C-MOS	1	U7	04713	14016
15	. . VACTROL	1	VTL1	49956	CK2182
16	. . TEST POINT	9	TP1-TP9	71279	T29
17	. . CONNECTOR, 25 PIN	1	J1	22526	65001-036
18	. IEEE 488 INTERFACE UNIT ASSY	REF	6-2/37,6-11	14028	552114
19	. . SUPPORT PLATE, INTERFACE	1	6-11/1		3066
20	. . HEX STANDOFF, JACK SCREW	2	6-11/2	50440	0380-0643

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 32 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . STANDOFF, 6-32 x 1/8	2	6-11/3	05394	KFB3-632-4
2	. . WASHER, FLAT	2	6-11/4		
3	. . IEEE 488 INTERFACE BOARD ..... ASSY	1	6-11/5	14028	552114-1000
4	. . . RES, 1K ±5%, 1/4 W	1	R1	24546	C4-102J
5	. . . RES NETWORK, 2.2K	1	RN1		3135
6	. . . CAP, 100uF ±20%, 10 V	1	C1	55680	TLB1A101M
7	. . . INT CKT, TTL	1	U1	01295	74LS240
8	. . . INT CKT, TTL	1	U2	01295	74LS32
9	. . . INT CKT, TTL	1	U3	01295	74LS04
10	. . . INT CKT, INTERFACE	4	U4-U7	04713	MC3448A
11	. . . INT CKT, PERIPHERAL	1	U8	34649	8291
12	. . . SOCKET, IC, 40 PIN	1	REF U8	01295	C8840-01
13	. . . CONNECTOR, IEEE 488, 24 PIN ..	1	J2	02660	57-20240-8
14	. . . SWITCH, 16 PIN, DIP	1	SW1	81073	76B08
15	. . . TEST POINTS	3	TP0-TP2	71279	T29
16	. . . CONNECTOR/CABLE ASSY, 34 PIN .	1	J1		3071-3
17	. RS-232C INTERFACE UNIT ASSY	REF	6-2/38, 6-12	14028	552115
18	. . SUPPORT PLATE, INTERFACE	1	6-12/1		3066
19	. . STANDOFF, 6-32 x 1/8	2	6-11/2	05394	KFB3-632-4
20	. . NUT, MODIFIED	2	6-12/3		3121

Table 6-2. Parts List for the TMA 3000 Tape Motion Analyzer (Sheet 33 of 33)

ITEM NO.	DESCRIPTION 0 1 2 3 4 5	QTY	FIG./INDEX OR REF SYM	MFR CODE	MFR OR MIL PART NO.
1	. . SCREW, 6-32 x 3/8 PAN HEAD ..... PHIL	2	6-12/4		
2	. . RS-232C INTERFACE BOARD ASSY ...	1	6-12/5	14028	552115-1000
3	. . . RES, 10K ±5%, 1/4 W	2	R1,R2	24546	C4-103J
4	. . . CAP, 47uF ±20%, 16 V	3	C1-C3	55680	ULB1C470M
5	. . . DIODE, SWITCHING	2	CR1,CR2	07263	1N4148
6	. . . INT CKT, TTL	1	U1	01295	74LS32
7	. . . INT CKT, PERIPHERAL	1	U2	34649	8251A
8	. . . INT CKT, BAUD RATE GEN	1	U3	52840	WD1943
9	. . . INT CKT, INTERFACE	1	U4	04713	MC1488
10	. . . INT CKT, INTERFACE	1	U5	04713	MC1489
11	. . . SOCKET, IC, 28 PIN	1	REF U2	01295	C8828-01
12	. . . CONNECTOR, RS232, 25 PIN	1	J1	02660	17-10250-11
13	. . . SWITCH, 8 PIN, DIP	1	SW1	81073	76B04
14	. . . CRYSTAL, 5.0688 MHz	1	Y1		3139
15	. . . TEST POINTS	4	TP0-TP3	71279	T29
16	. . . CONNECTOR/CABLE ASSY, 34 PIN .	1	J2		3071-3

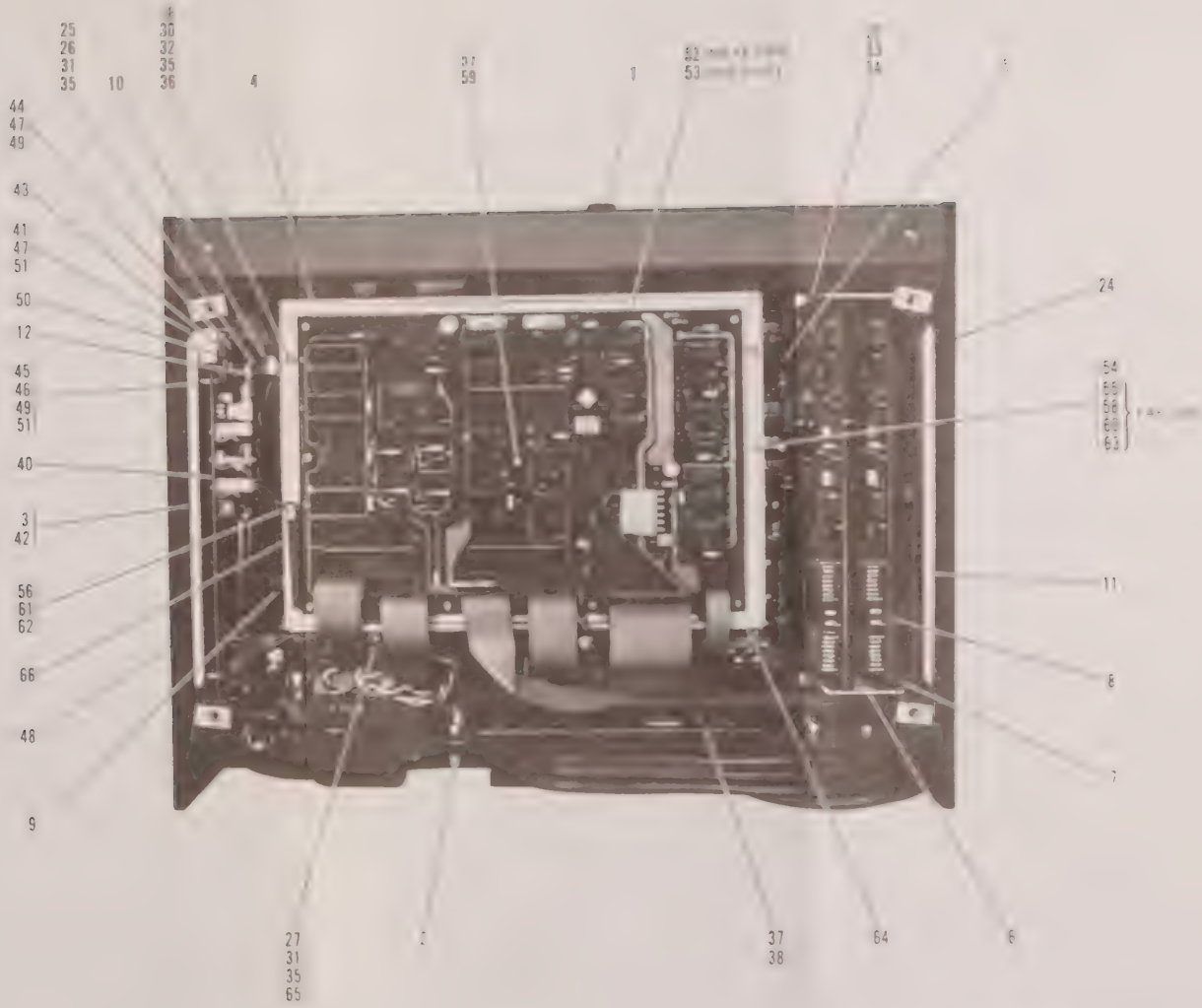
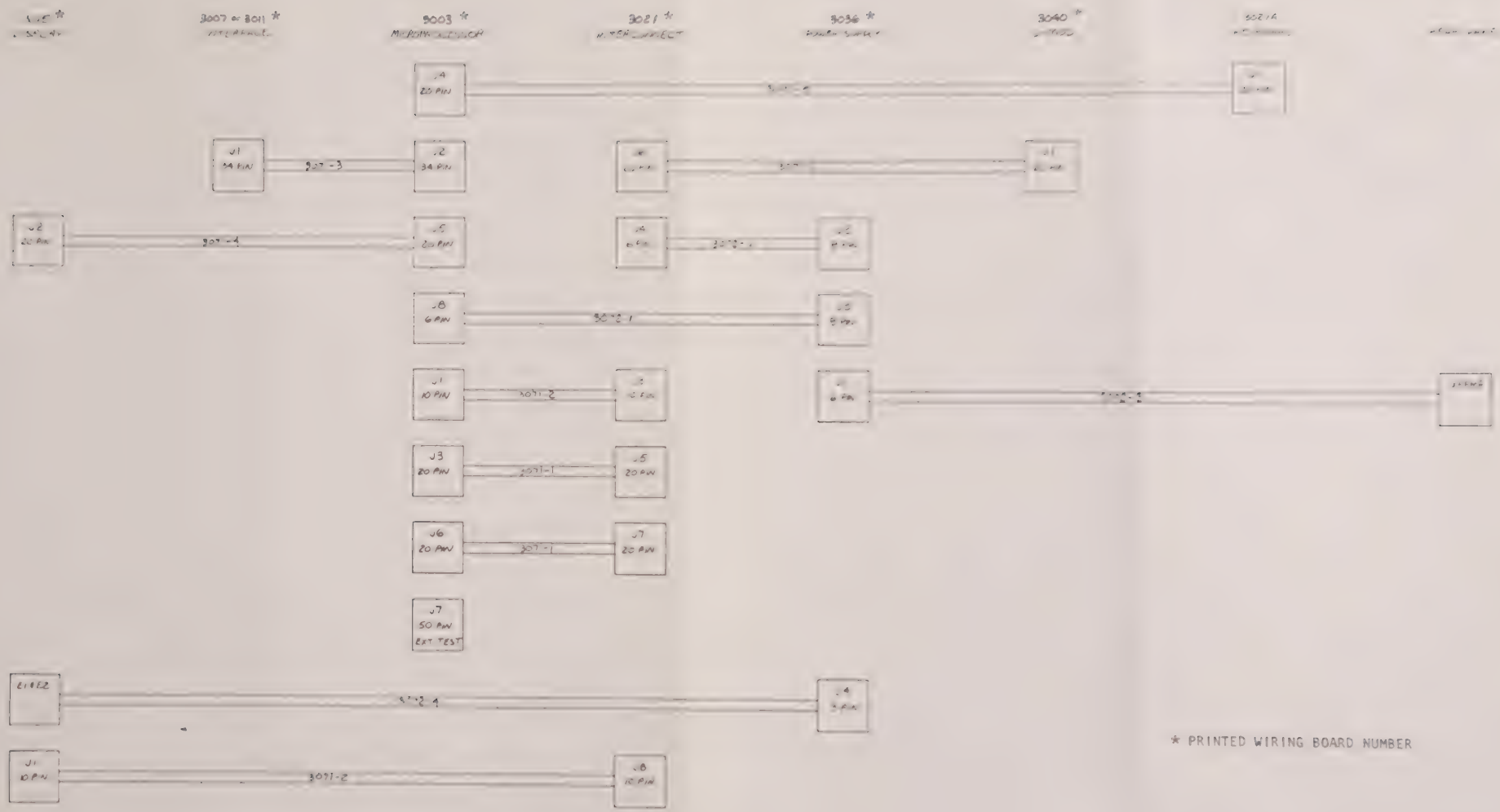
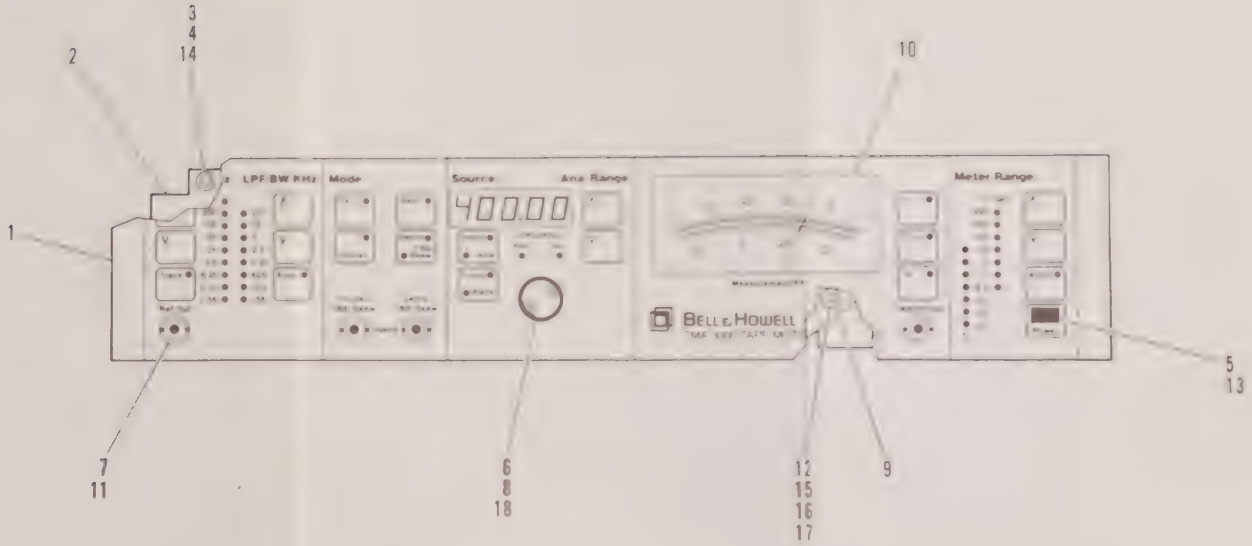


Figure 6-2. [illegible] pe Motion Analyzer



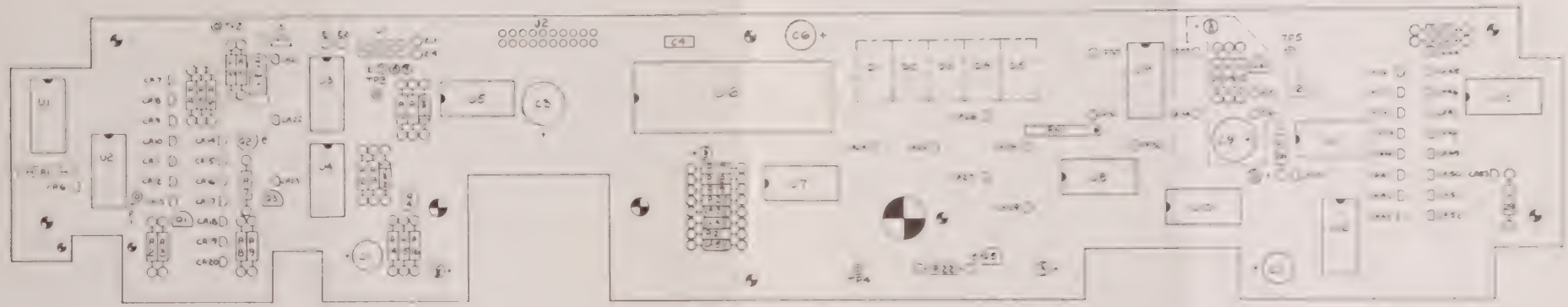
* PRINTED WIRING BOARD NUMBER

Figure 6-2. TMA 3000 Tape Motion Analyzer
(Sheet 2 of 2)



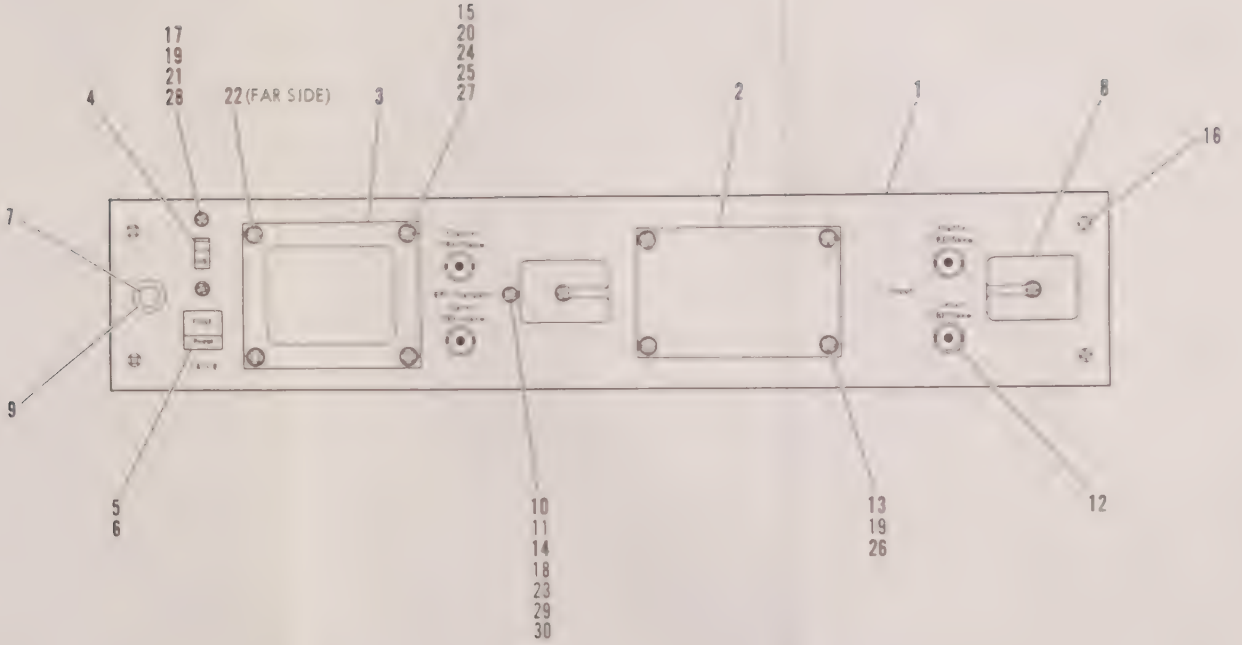
D-552100-2000 (REF)

Figure 6-3. Front Panel Assembly



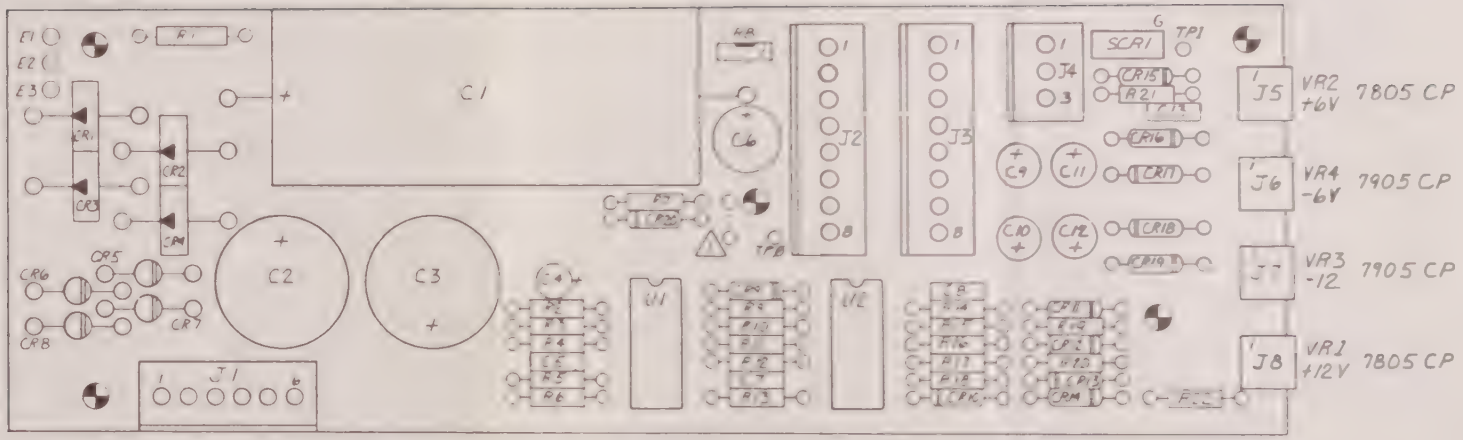
D-552100-2100-B (REF)

Figure 6-4. Front Panel Display Board Assembly



D-552100-3000 (REF)

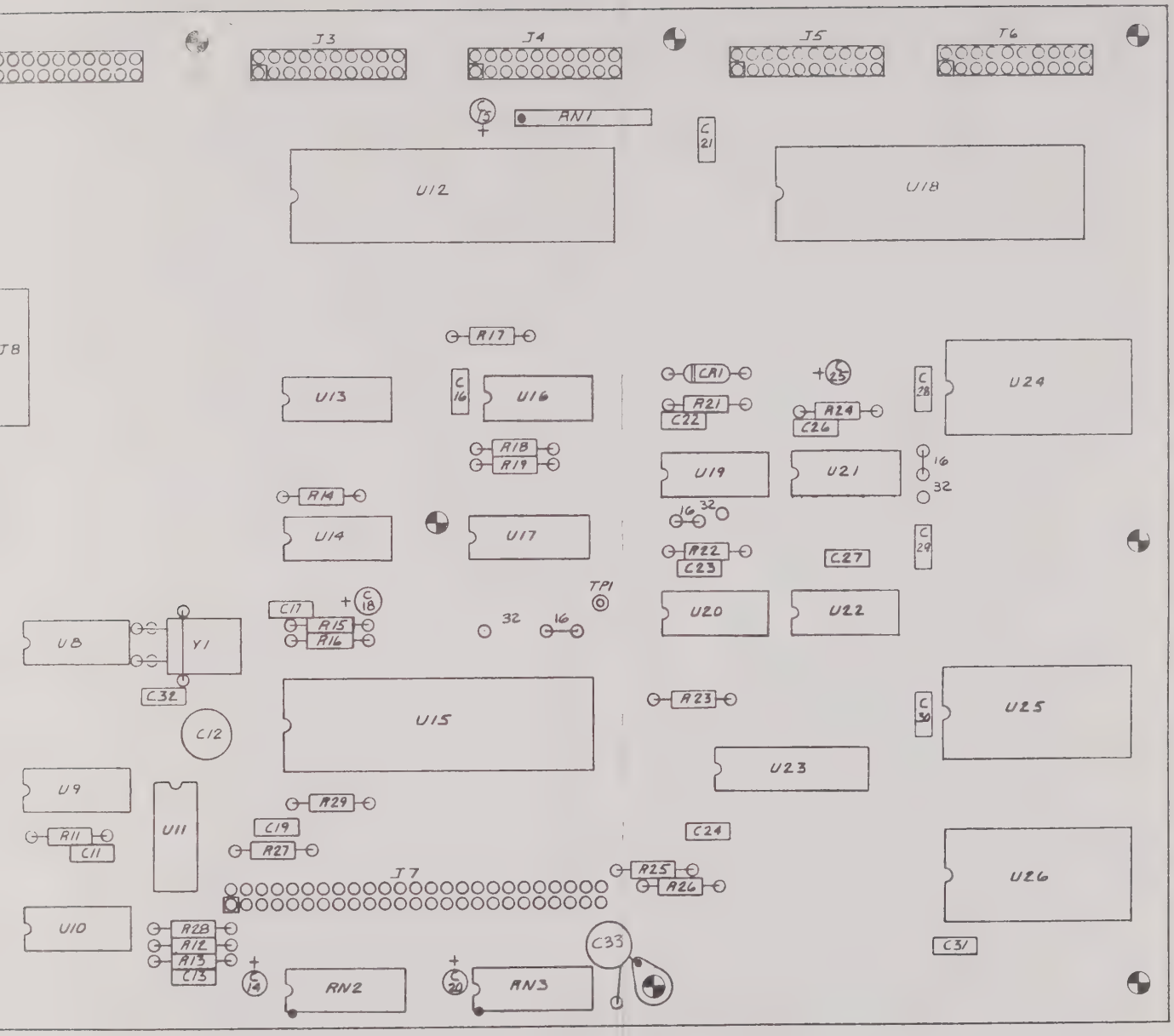
Figure 6-5. Rear Panel Assembly



D-552100-4100 (REF)

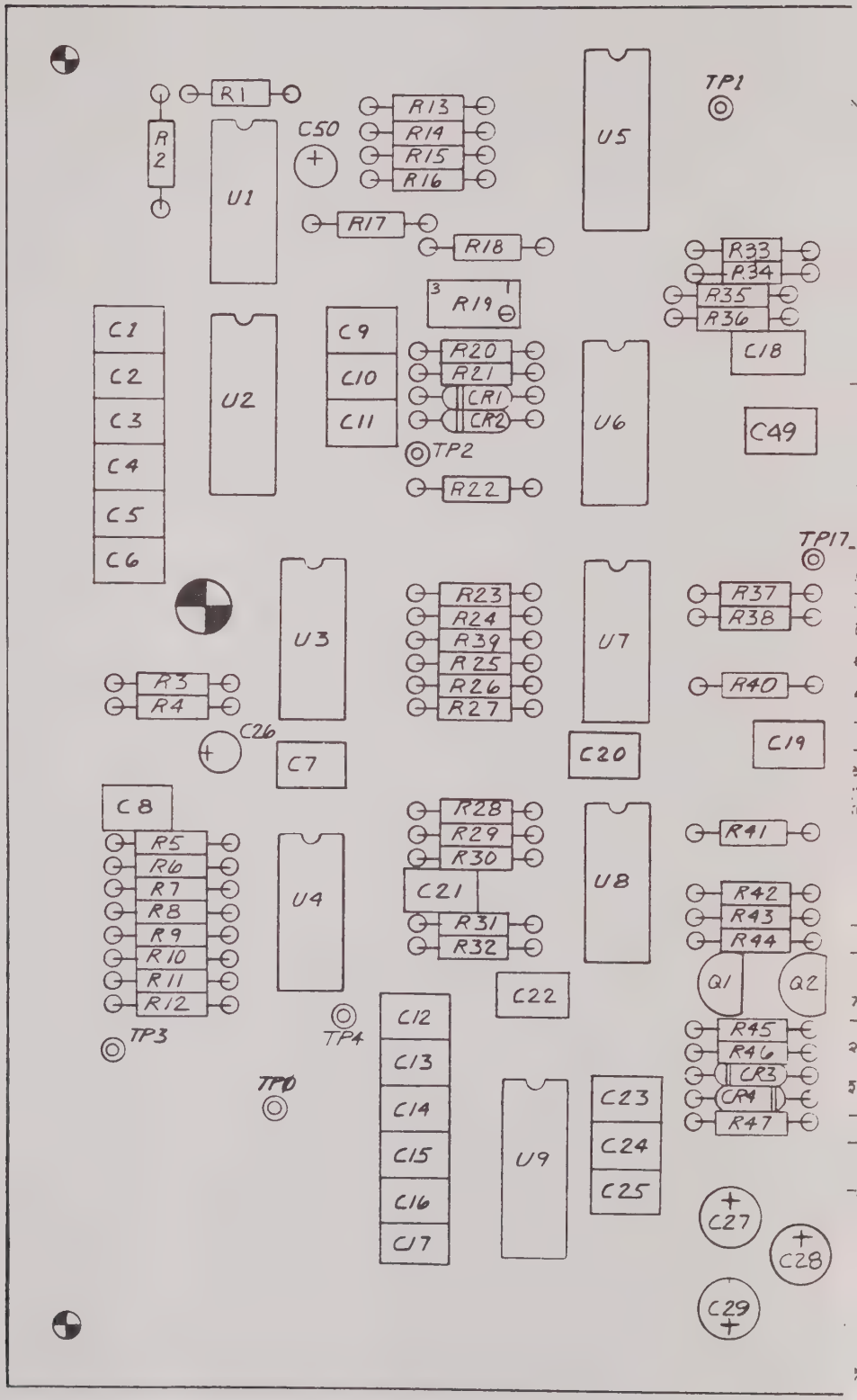
Figure 6-6. Power Supply Assembly

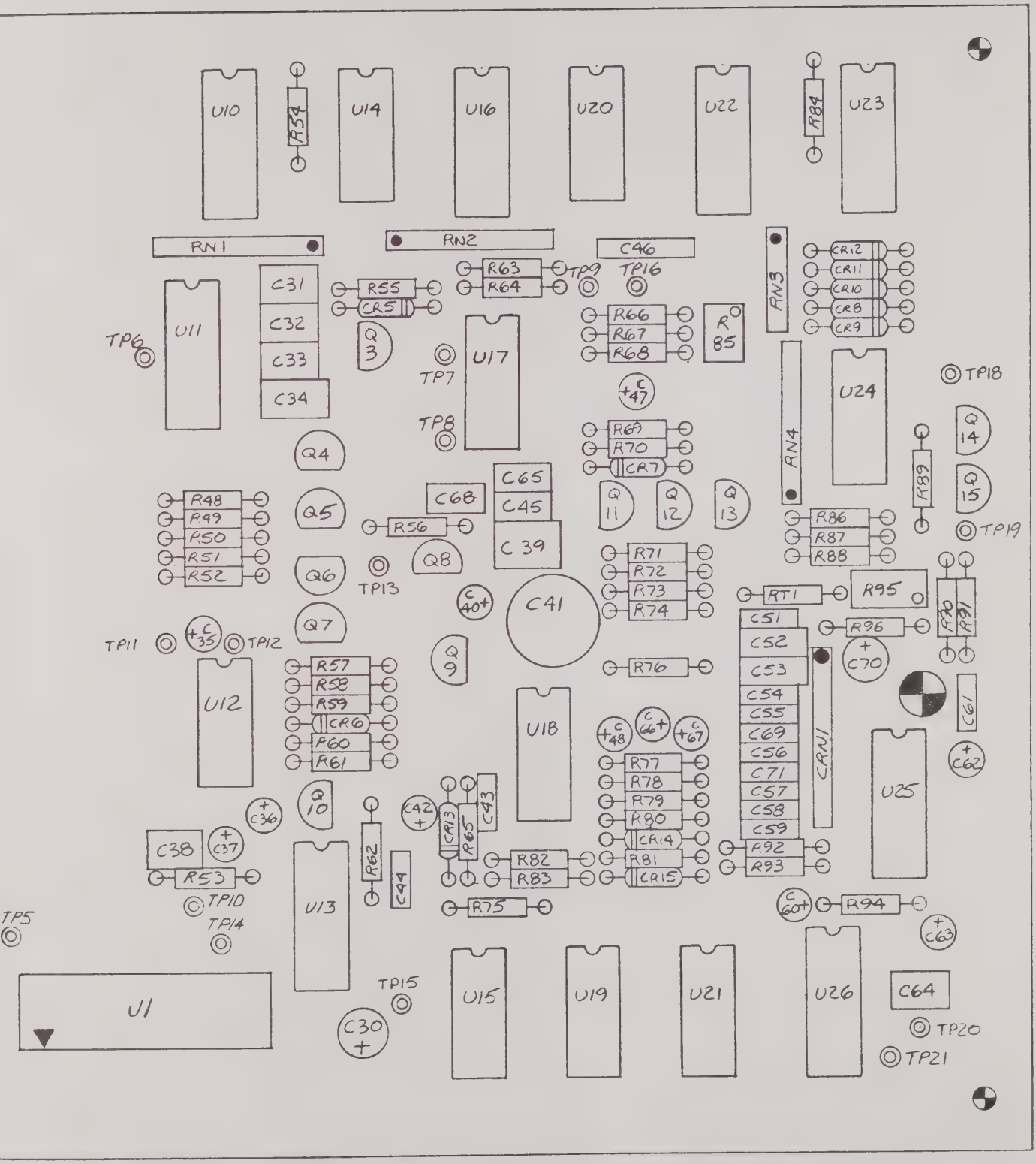
T1
J1
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
U1
U2
U3
U4
U5
U6
U7
TP2
TP0



D-552100-7000 (REF)

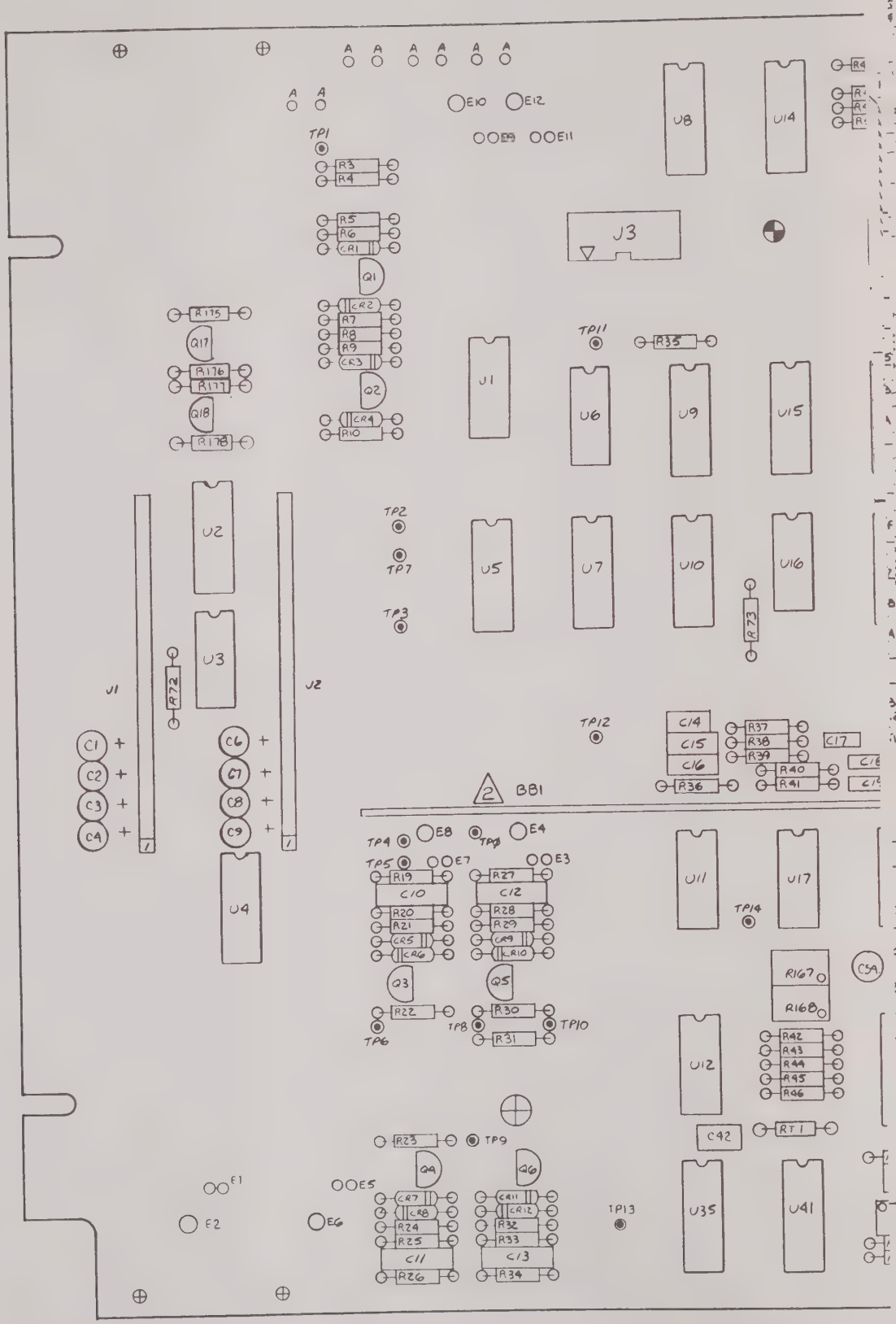
Figure 6-7. Microprocessor Board Assembly

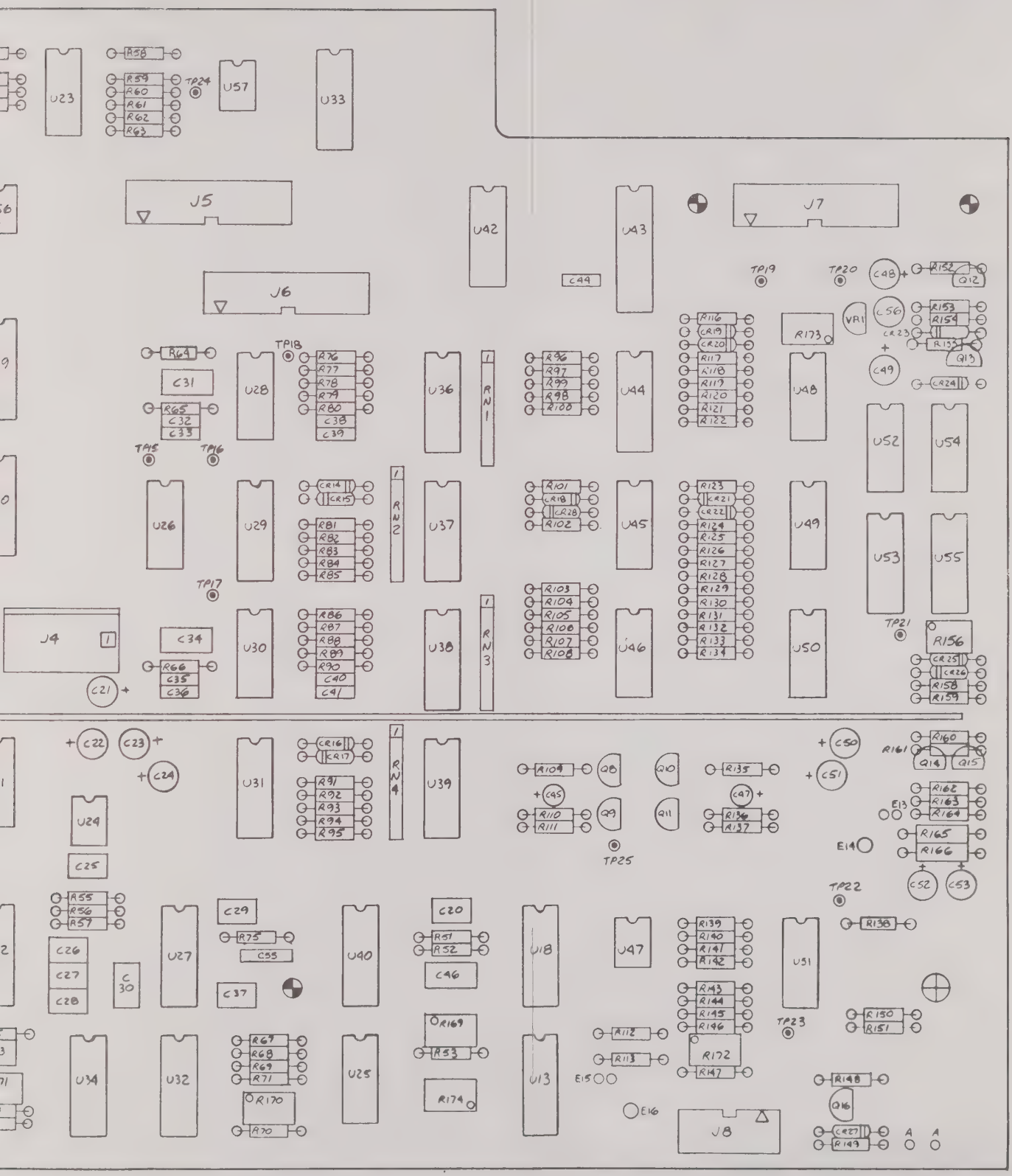

R1
R2
U1
C50
R13
R14
R15
R16
R17
R18
U5
TP1
R33
R34
R35
R36
C18
R19
C1
C2
C3
C4
C5
C6
U2
C9
C10
C11
R20
R21
CR1
CR2
TP2
R22
U6
C49
TP17
U3
R23
R24
R39
R25
R26
R27
U7
R37
R38
R40
R3
R4
C26
C7
C20
C19
C8
R5
R6
R7
R8
R9
R10
R11
R12
U4
R28
R29
R30
C21
R31
R32
U8
R41
R42
R43
R44
Q1
Q2
C22
TP3
TP4
TP0
C12
C13
C14
C15
C16
C17
U9
C23
C24
C25
R45
R46
CR3
CR4
R47
C27
C28
C29



D-552100-8000-D (REF)

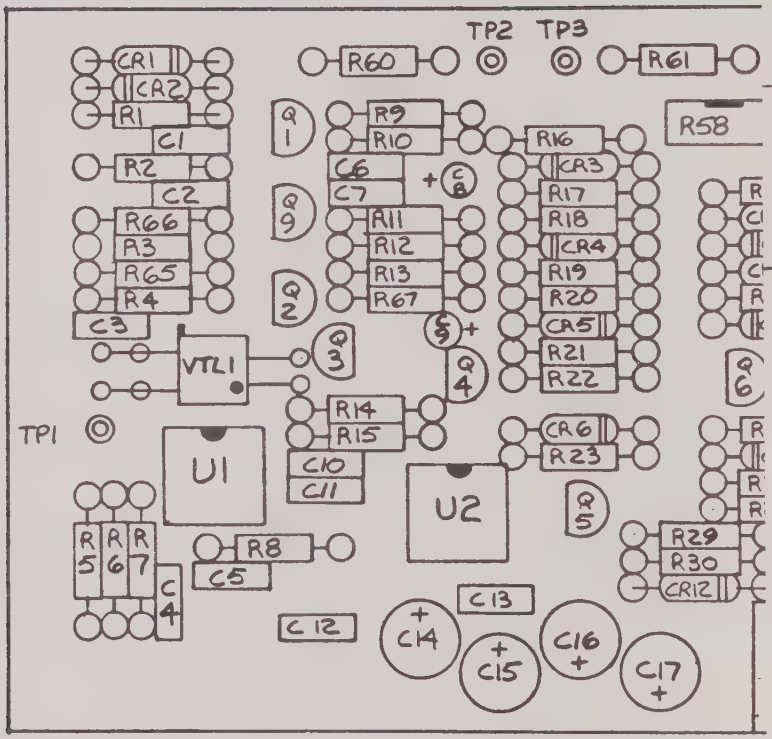
Figure 6-8. D-MOD Board Assembly


A
E10
E12
E11
TP1
R3
R4
R5
R6
CR1
Q1
CR2
R7
R8
R9
CR3
Q2
CR4
R10
R175
Q17
R176
R177
Q18
R178
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U14
U15
U16
U17
U35
U41
J1
J2
J3
TP2
TP7
TP3
TP11
R35
TP12
R72
R73
C1
C2
C3
C4
C6
C7
C8
C9
C14
C15
C16
C17
R36
R37
R38
R39
R40
R41
BB1
TP4
TP8
E8
E4
TP5
E7
E3
R19
C10
R20
R21
CR5
CR6
R27
C12
R28
R29
CR9
CR10
Q3
Q5
R22
R30
R31
TP6
TP8
TP10
TP14
R167
R168
C59
R42
R43
R44
R45
R46
C42
RT1
R23
TP9
Q4
Q6
E1
E5
E2
E6
CR7
CR8
R24
R25
C11
R26
CR11
CR12
R32
R33
C13
R34
TP13



D-552100-6000-B (REF)

Figure 6-9. Interconnect Board Assembly


TP2
TP3
CR1
CR2
R1
C1
R2
C2
R66
R3
R65
R4
C3
VTL1
TP1
U1
R5
R6
R7
C4
R8
C5
C12
R60
R61
R58
Q1
R9
R10
C6
C7
C8
Q9
R11
R12
R13
R67
Q2
C9
Q3
Q4
R14
R15
C10
C11
U2
R16
CR3
R17
R18
CR4
R19
R20
CR5
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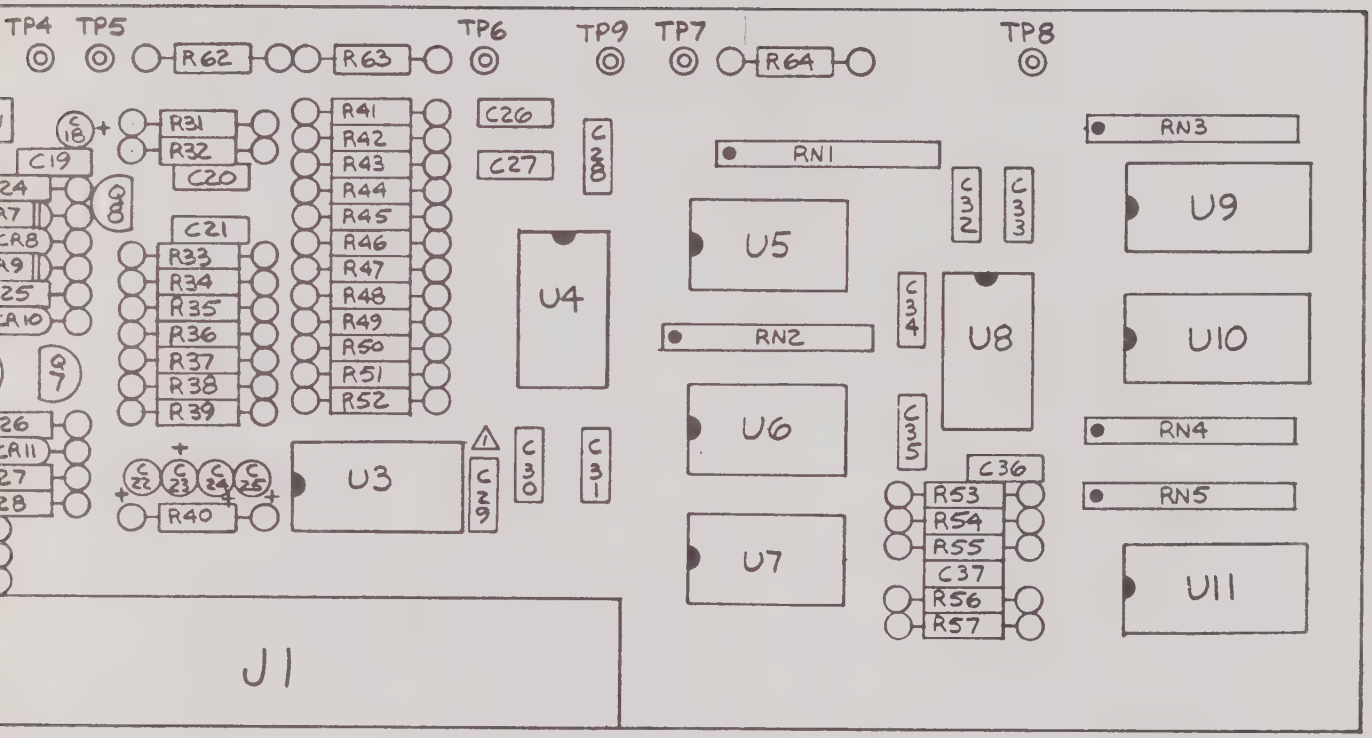
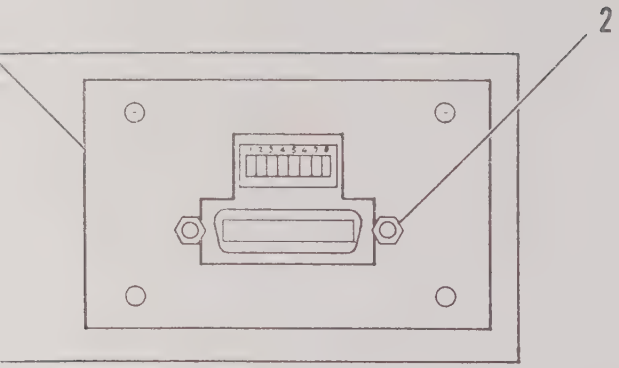
R30
CR12
C13
C14
C15
C16
C17

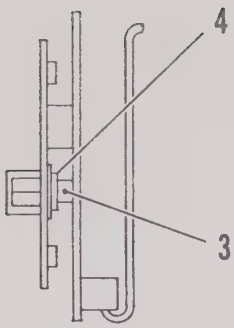


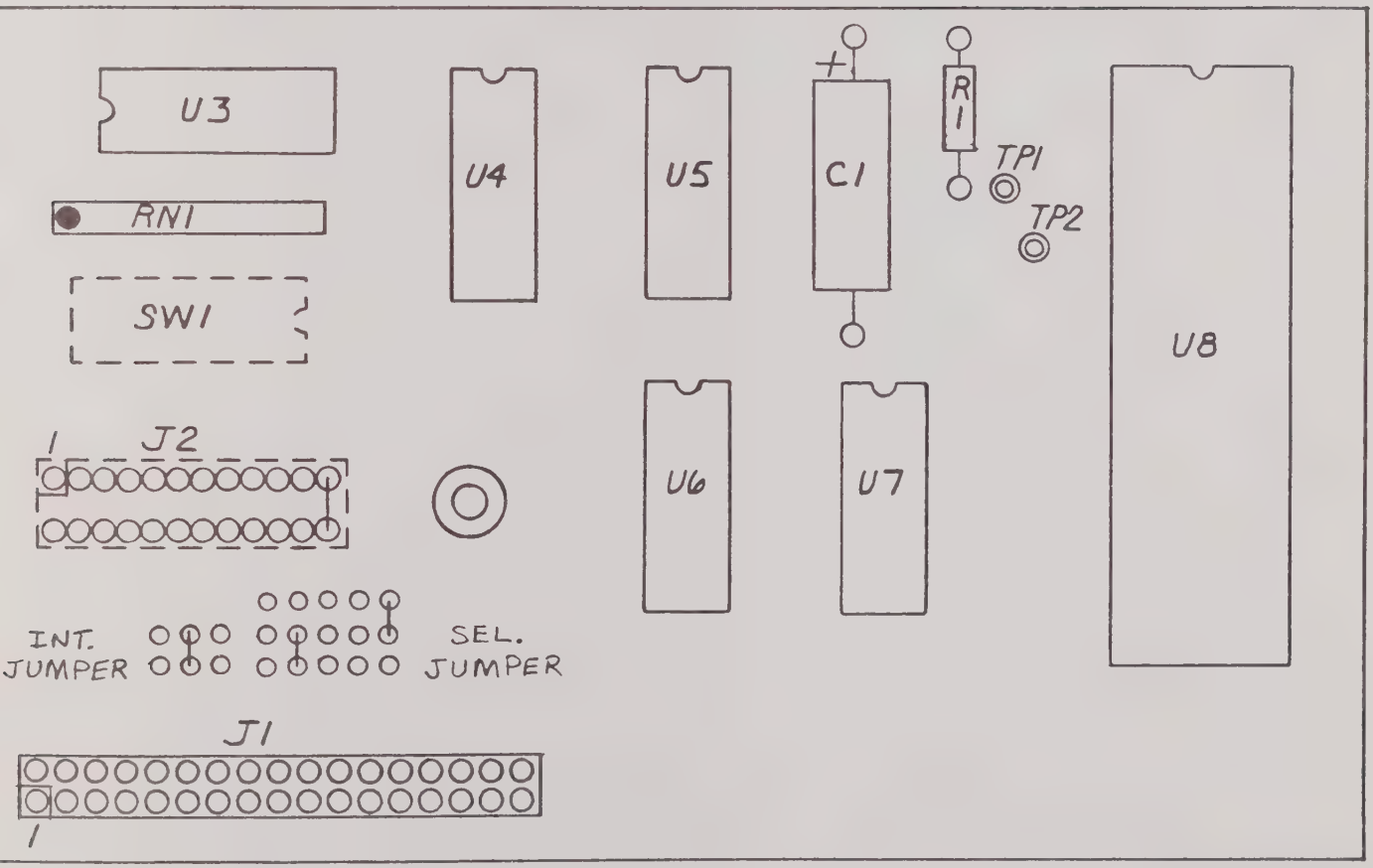
D-552100-9000-C (REF)

Figure 6-10. Input Channel Conditioner Assembly

1
5
TP0
U1
U2



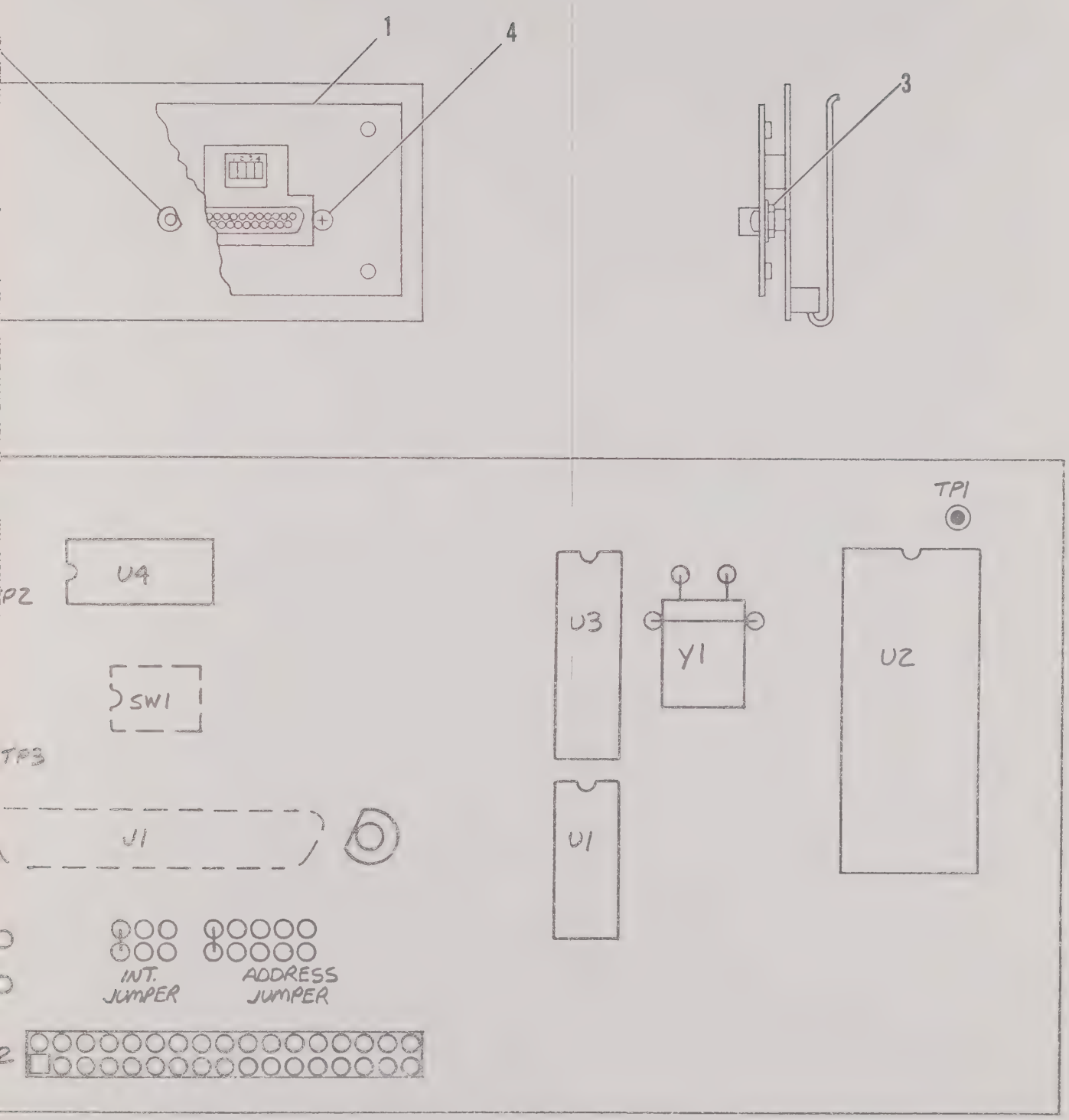




D-552114-1000 (REF)

Figure 6-11. IEEE 488 Interface Unit Assembly

2
5
TPΦ
U5
C3
CR2
C2
C1
CR1
R2
R1



D-552115-1000 (REF)

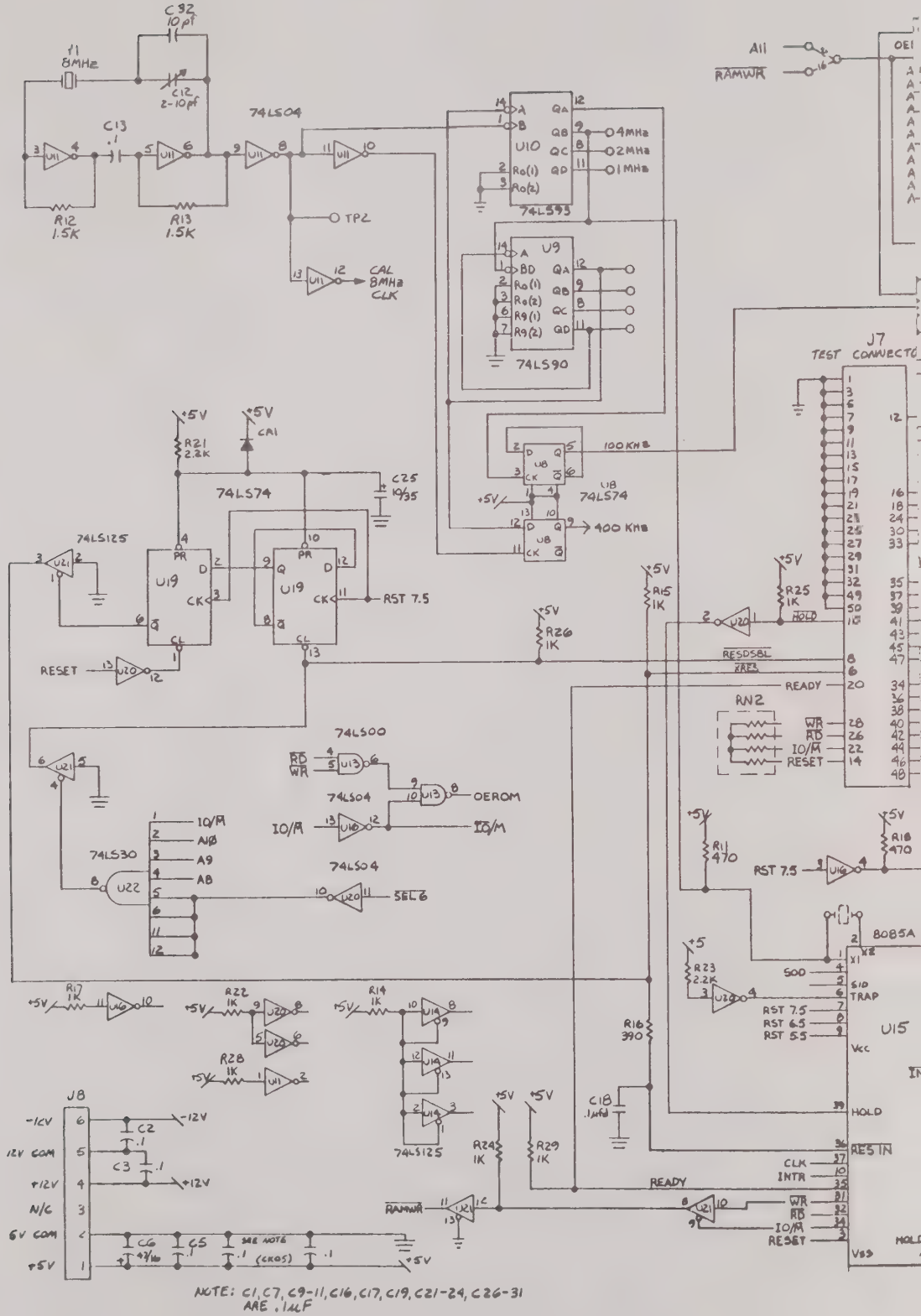
Figure 6-12. RS-232C Interface Unit Assembly

SECTION VII

SCHEMATICS

7-1. SCOPE OF SECTION.

7-2. This section contains schematics for the TMA 3000 Tape Motion Analyzer.


C32 10pf
Y1 8MHz
C12 2-10pf
C13 .1
74LS04
R12 1.5K
R13 1.5K
TP2
CAL 8MHz CLK
U10
74LS393
0.4MHz
0.2MHz
0.1MHz
U9
74LS90
A11
RAMWR
OE
J7
TEST CONNECTOR
+5V
R21 2.2K
CR1
C25 10/35
74LS74
100KHz
400 KHz
74LS125
U19
RST 7.5
RESET
R15 1K
R25 1K
HOLD
R26 1K
RESDSBL
READY
RN2
WR
RD
IO/M
RESET
74LS00
74LS04
OEROM
IO/M
74LS30
SEL6
R17 1K
R22 1K
R28 1K
R14 1K
R16 390
R11 470
R18 470
RST 7.5
8085A
R23 2.2K
SOD
SID
TRAP
RST 7.5
RST 6.5
RST 5.5
Vcc
HOLD
RESIN
CLK
INTR
WR
RD
IO/M
RESET
Vss
C18 .1μfd
R24 1K
R29 1K
RAMWR
READY
J8
-12V
12V COM
+12V
N/C
5V COM
+5V
C2 .1
C3 .1
C6 47/16
C5 .1
SEE NOTE (CROS)
.1
-12V
+12V
+5V
NOTE: C1, C7, C9-11, C16, C17, C19, C21-24, C26-31 ARE .1μF

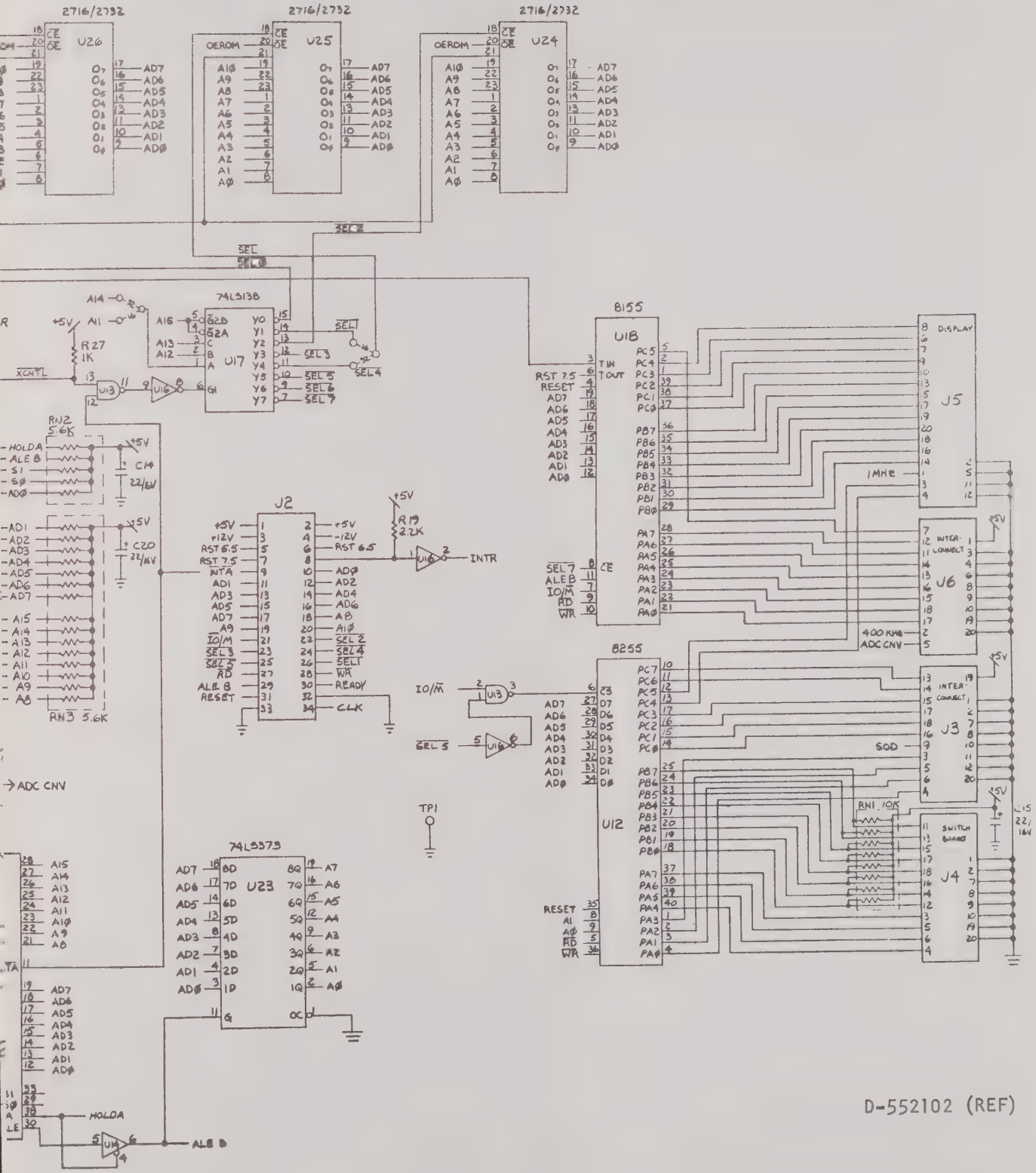
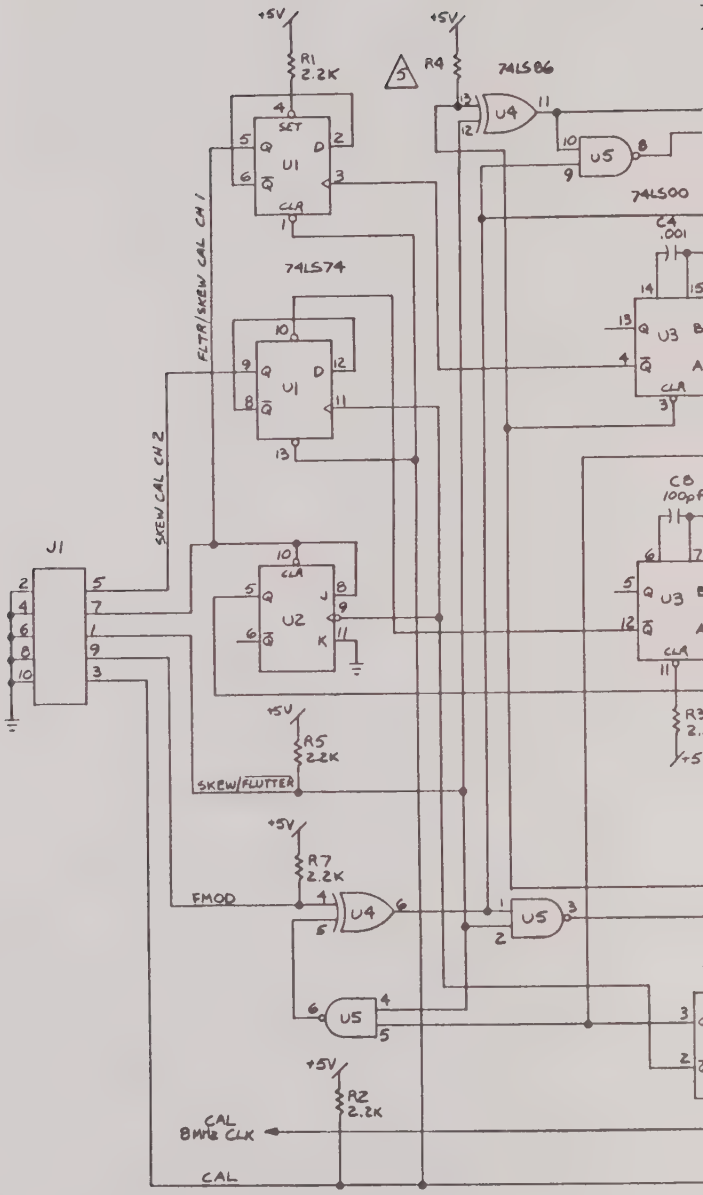
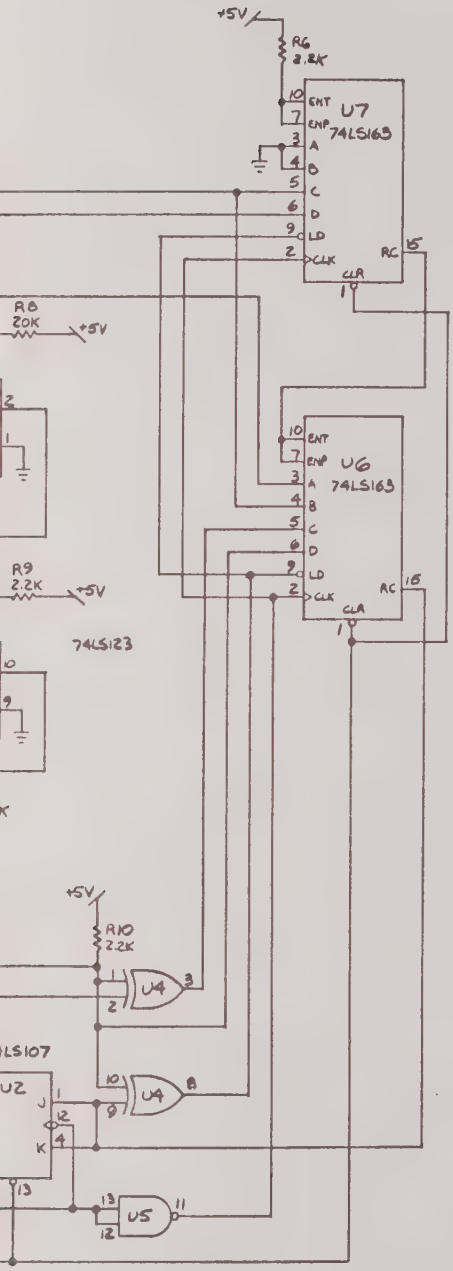


Figure 7-1. Schematic, Microprocessor Unit (Sheet 1 of 2)


+5V
R1
2.2K
R4
74LS86
U4
U5
74LS00
C4
.001
74LS74
U1
U3
FLTR/SKEW CAL CH 1
SKEW CAL CH 2
J1
U2
C5
100pF
R5
2.2K
SKEW/FLUTTER
R7
2.2K
FMOD
R2
2.2K
CAL
8MHz CLK
CAL



TP Ø

5. OPTIONAL, NOT USED ON STD. MODEL.
4. DIODES ARE IN4148.
3. TRANSISTORS - NAN'S 2N3904, ANP'S 2N3906.
2. ¼ RESISTOR VALUES WITH THREE SIGNIFICANT DIGITS ARE ± 1%.
1. RESISTORS ARE EXPRESSED IN OHMS (Ω) ¼W ± 5%.
NOTES: UNLESS OTHERWISE SPECIFIED

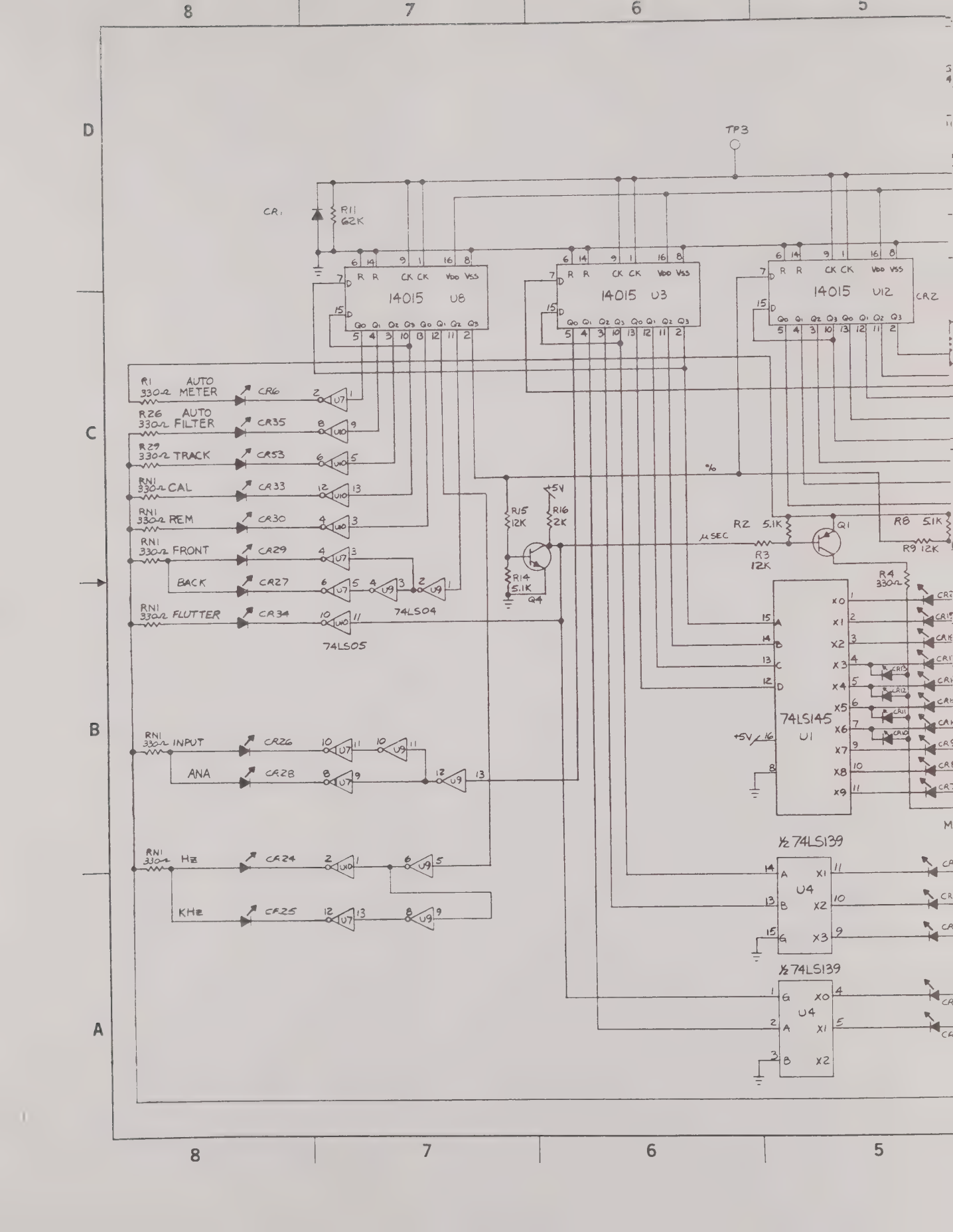
REF	PART #	+5V	5V GND	+12V	-12V	12VGND
U26	2732	24	12			
U26	2716	24	12			
U25	2732	24	12			
U25	2716	24	12			
U24	2732	24	12			
U24	2716	24	12			
U23	74LS373	20	10			
U22	74LS30	14	7			
U21	74LS125	14	7			
U20	74LS09	14	7			
U19	74LS74	14	7			
U18	8155	40	20			
U17	74LS138	16	8			
U16	74LS04	14	7			
U15	8085A	40	20			
U14	74LS125	14	7			
U13	74LS00	14	7			
U12	8255	26	7			
U11	74LS04	14	7			
U10	74LS93	5	10			
U9	74LS90	5	10			
U8	74LS74	14	7			
U7	74LS163	16	8			
U6	74LS163	16	8			
U5	74LS00	14	7			
U4	74LS86	14	7			
U3	74LS123	16	8			
U2	74LS107	14	7			
U1	74LS74	14	7			

IC POWER TABULATION

LAST REF DES		
R29	TP2	
C32		
U26		
CR1		
RN3		
Y1		
J8		
DELETED		
R20		

D-552102 (REF)

Figure 7-1. Schematic, Microprocessor Unit (Sheet 2 of 2)


TP3
CR1
R11
62K
14015 U8
14015 U3
14015 U12
CR2
R1 330Ω AUTO METER CR6
R26 330Ω AUTO FILTER CR35
R29 330Ω TRACK CR53
RN1 330Ω CAL CR33
RN1 330Ω REM CR30
RN1 330Ω FRONT CR29
BACK CR27
RN1 330Ω FLUTTER CR34
74LS04
74LS05
RN1 330Ω INPUT CR26
ANA CR28
RN1 330Ω Hz CR24
KHz CR25
+5V
R15 12K
R16 2K
R14 5.1K
Q4
%
μSEC
RZ 5.1K
R3 12K
Q1
R8 5.1K
R9 12K
R4 330Ω
74LS145 U1
½ 74LS139 U4
½ 74LS139 U4

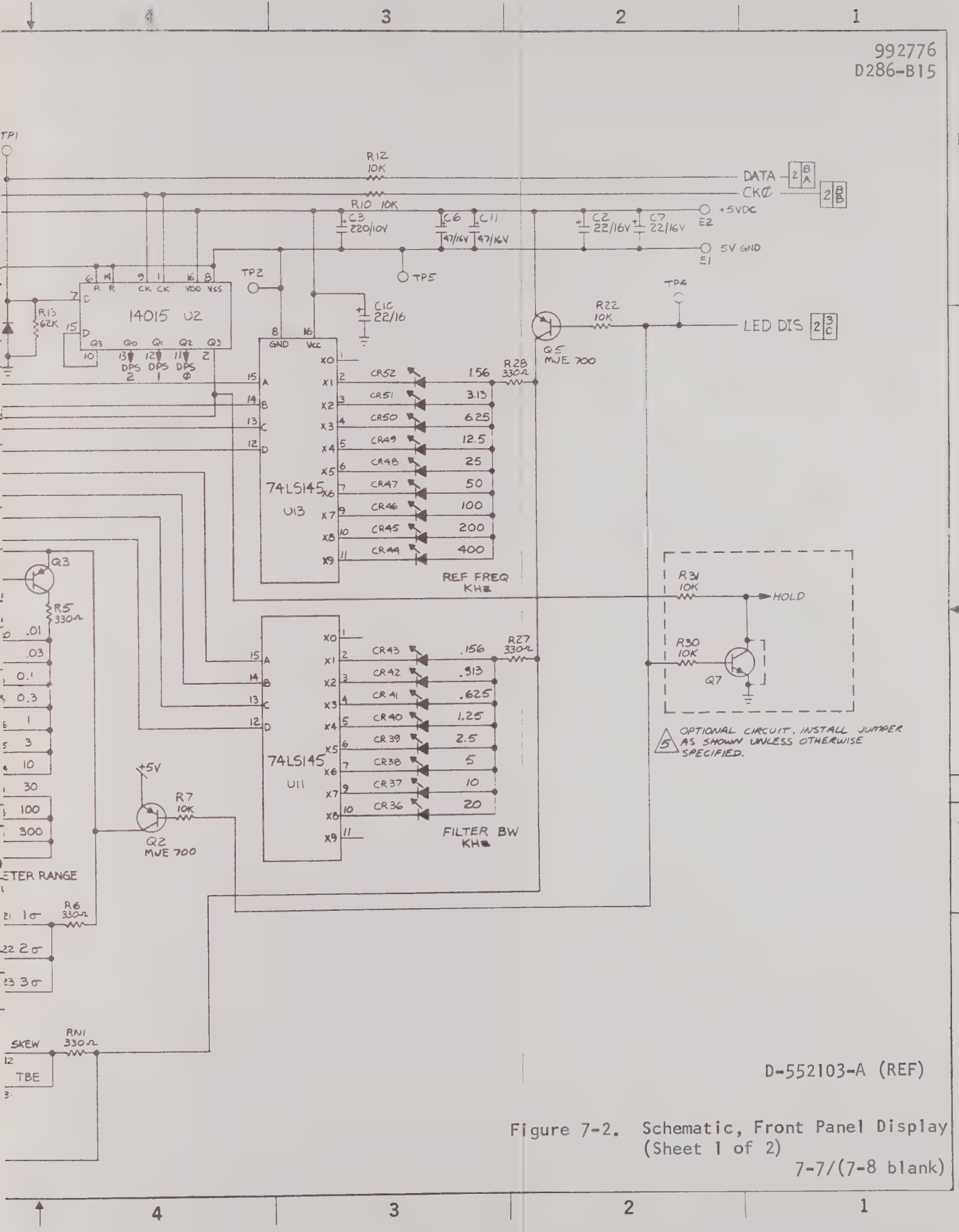
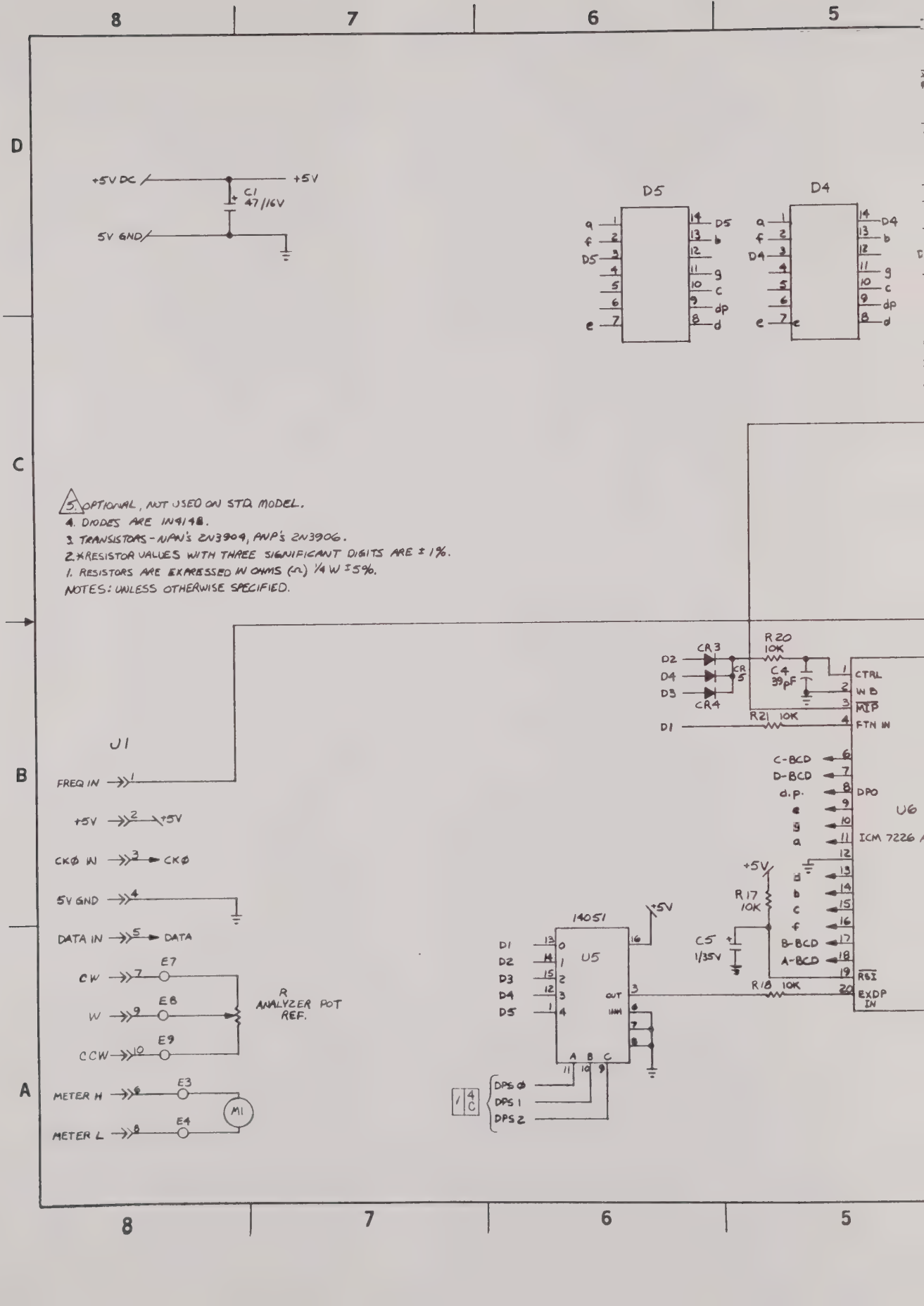
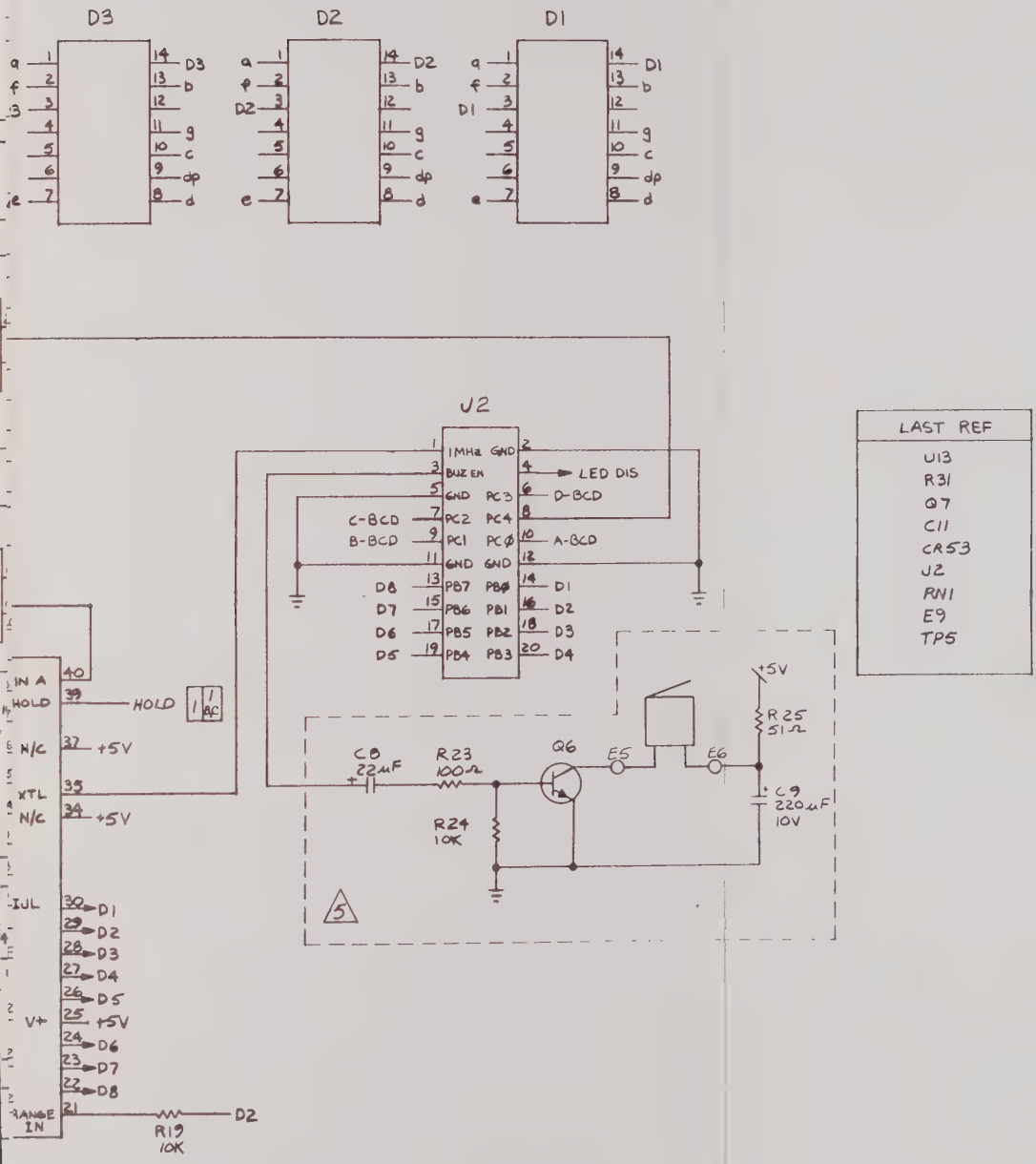


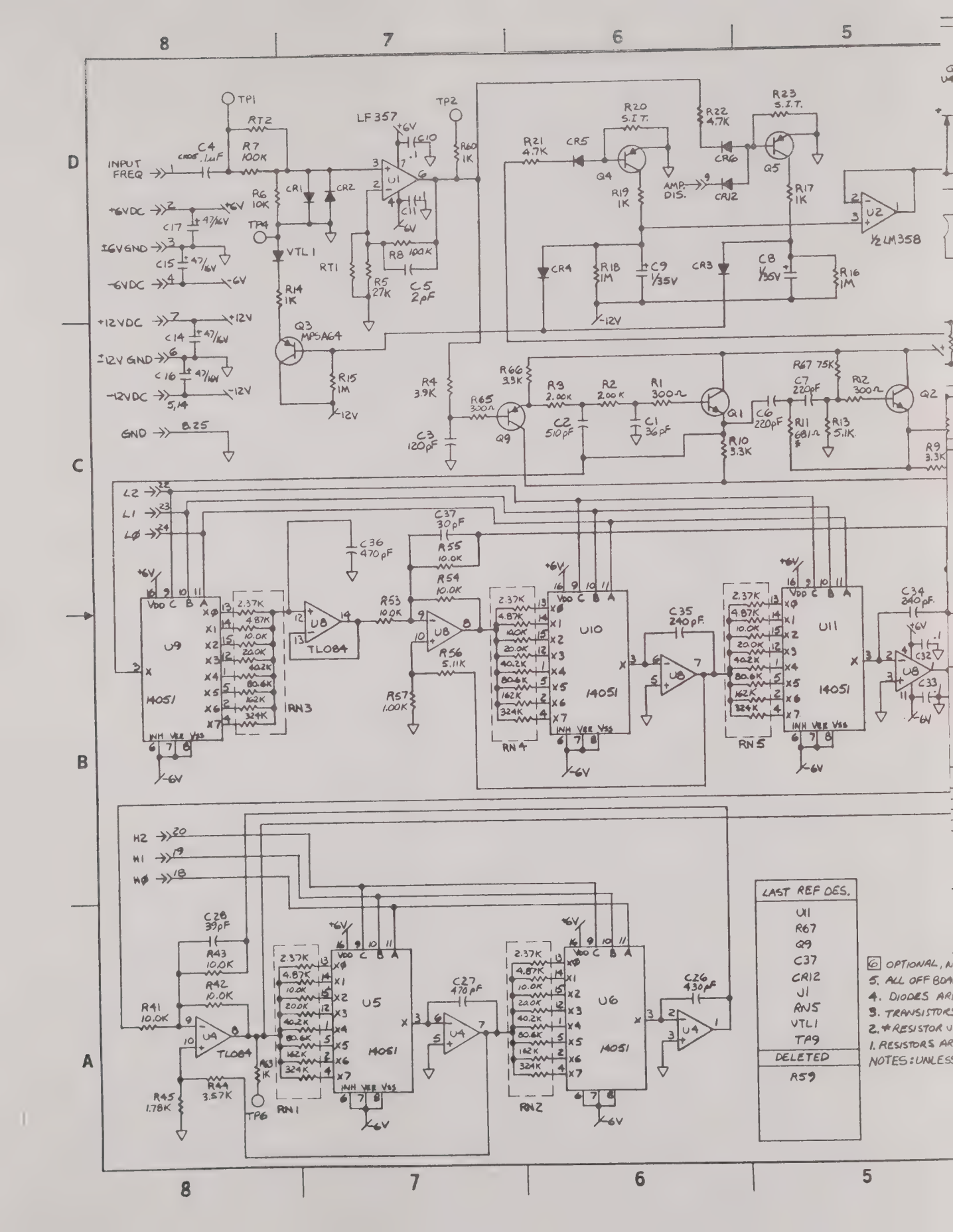
Figure 7-2. Schematic, Front Panel Display (Sheet 1 of 2)

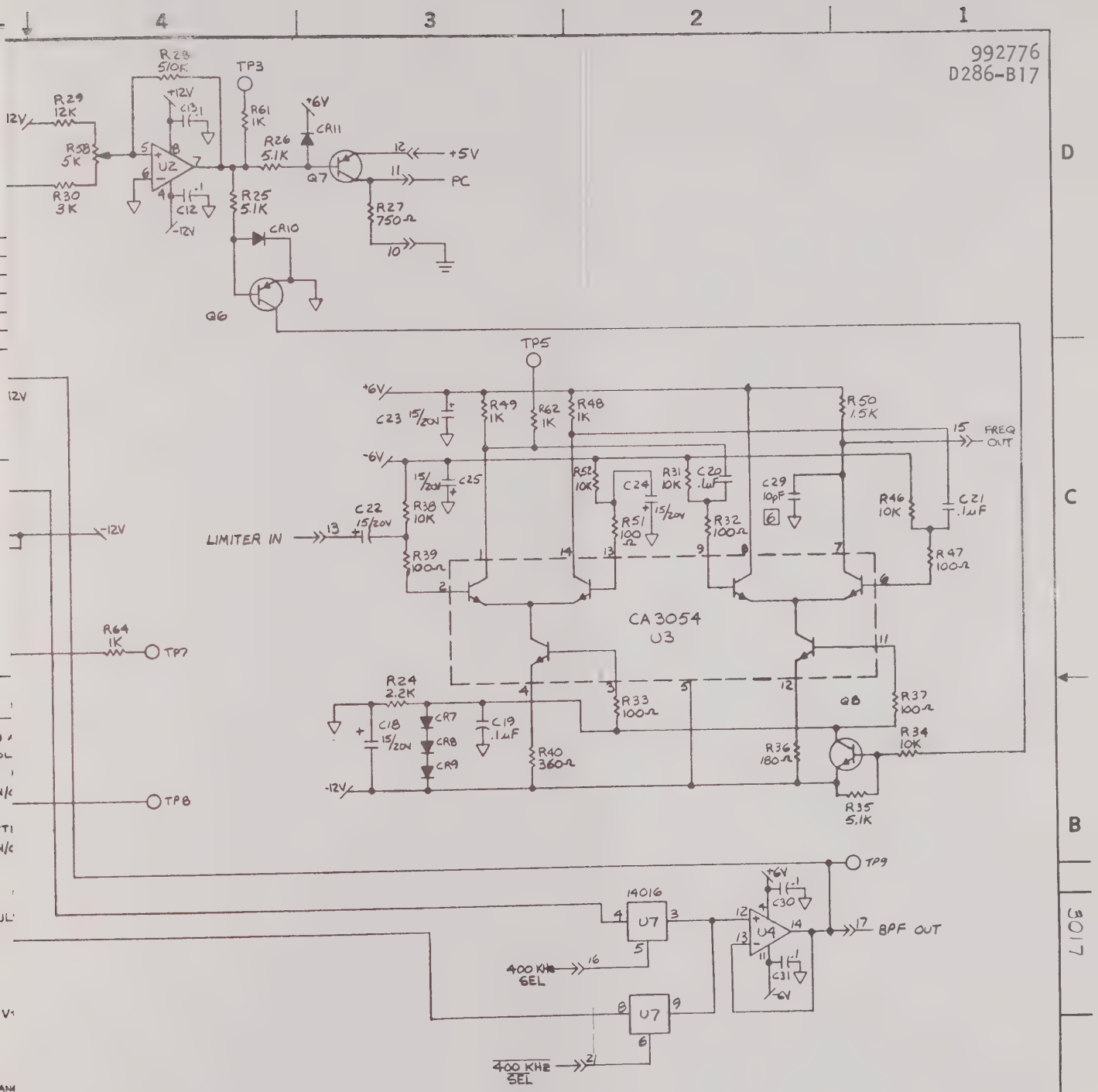

8
7
6
5
D
C
B
A
+5V DC
+5V
C1
47/16V
5V GND
D5
D4
q
f
D5
D4
e
a
b
g
c
dp
d
5. OPTIONAL, NOT USED ON STD. MODEL.
4. DIODES ARE 1N914B.
3. TRANSISTORS - NPN's 2N3904, PNP's 2N3906.
2. *RESISTOR VALUES WITH THREE SIGNIFICANT DIGITS ARE ± 1%.
1. RESISTORS ARE EXPRESSED IN OHMS (Ω) ¼ W ±5%.
NOTES: UNLESS OTHERWISE SPECIFIED.
U1
FREQ IN
+5V
CKØ IN
CKØ
5V GND
DATA IN
DATA
CW
CCW
E7
E8
E9
R
ANALYZER POT
REF.
METER H
METER L
E3
E4
M1
CR3
CR4
CR5
D2
D4
D3
D1
R20
10K
C4
39pF
R21
10K
CTRL
W B
MTP
FTN IN
C-BCD
D-BCD
d.p.
DPO
U6
ICM 7226 A
R17
10K
C5
1/35V
R18
10K
B-BCD
A-BCD
R6I
EXDP IN
14051
U5
DPS Ø
DPS 1
DPS 2
1/4C



D-552013-A (REF)

Figure 7-2. Schematic, Front Panel Display (Sheet 2 of 2)

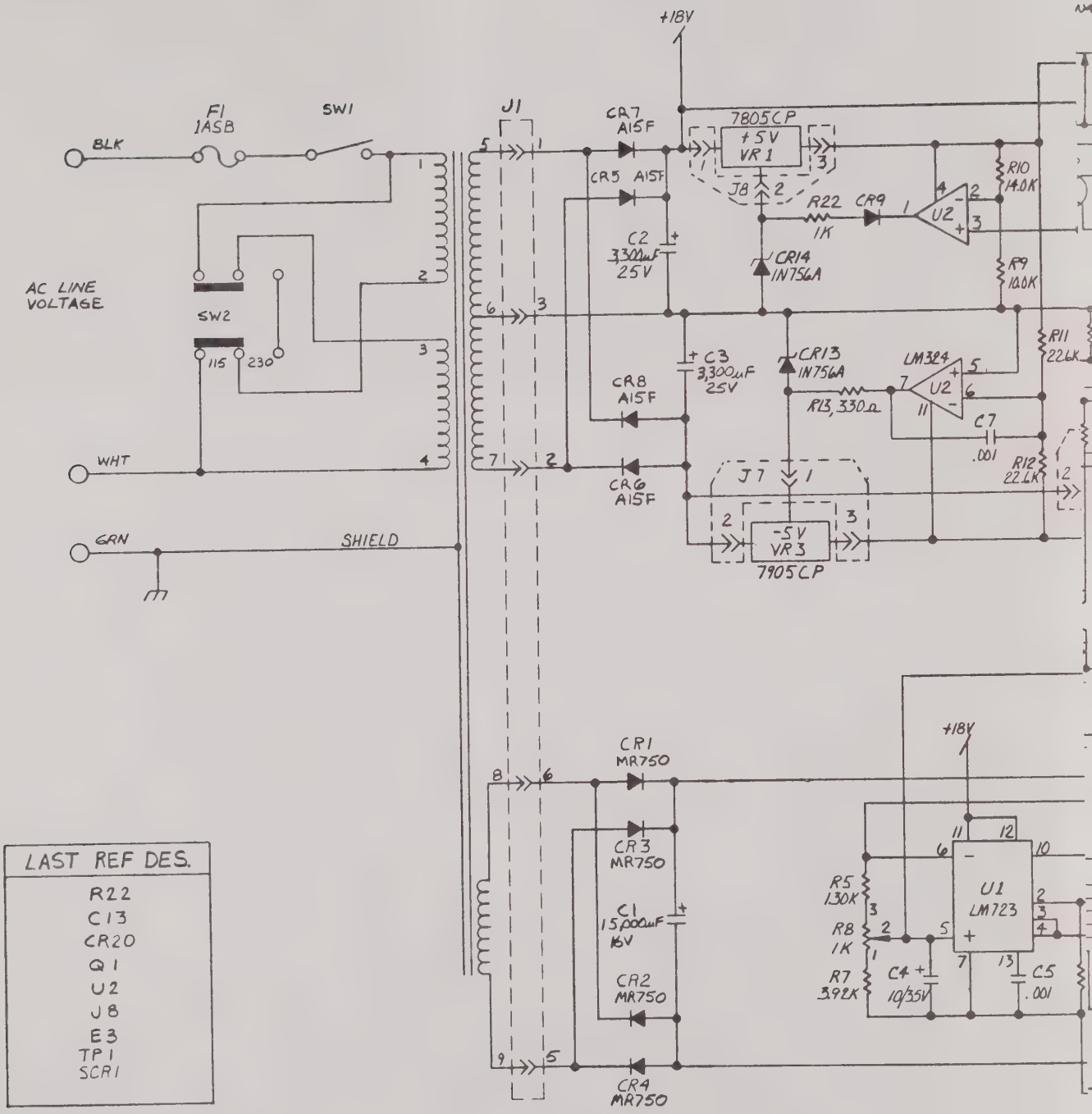

8
7
6
5
D
C
B
A
TP1
TP2
RT2
R7 100K
C4 .1μF
INPUT FREQ
LF357
+6V
C10 .1
R60 1K
U1
R6 10K
CR1
CR2
+6VDC
C17 47/6V
TP4
VTL1
RT1
R8 100K
R5 27K
C5 2pF
IGVGND
C15 47/6V
-6VDC
R14 1K
Q3 MPSA64
R15 1M
-12V
+12VDC
C14 47/6V
+12V
-12V GND
C16 47/6V
-12VDC
5,14
GND
8,25
R21 4.7K
CR5
R20 S.I.T.
R22 4.7K
R23 S.I.T.
Q4
Q5
CR6
CR12
AMP. DIS.
R19 1K
R17 1K
U2
½ LM358
CR4
R18 1M
C9 1/35V
CR3
C8 1/35V
R16 1M
R4 3.9K
R66 3.9K
R65 300Ω
Q9
R3 2.00K
R2 2.00K
R1 300Ω
Q1
C7 220pF
R67 75K
R12 300Ω
Q2
C6 220pF
R11 681Ω
R13 5.1K
C3 120pF
C2 510pF
C1 36pF
R10 3.3K
R9 3.3K
L2
L1
LØ
C36 470pF
C37 30pF
R55 10.0K
R54 10.0K
R53 10.0K
R56 5.11K
R57 1.00K
U9
14051
RN3
U8
TL084
U10
RN4
C35 240pF
U11
RN5
C34 240pF
C32 .1
C33
H2
H1
HØ
C28 39pF
R43 10.0K
R42 10.0K
R41 10.0K
R44 3.57K
R45 1.78K
R63 1K
TP6
U4
U5
RN1
C27 470pF
U6
RN2
C26 430pF
LAST REF DES.
U1
R67
Q9
C37
CR12
J1
RN5
VTL1
TP9
DELETED
R59
6 OPTIONAL, N
5. ALL OFF BOA
4. DIODES AR
3. TRANSISTORS
2. ★RESISTOR V
1. RESISTORS AR
NOTES: UNLESS



OT USED ON STD. MODEL.
RD CONNECTIONS GO THROUGH U1.
E IN4148
S-NAN's 2N3909, ANP's 2N3906.
ALUES WITH THREE SIGNIFICANT DIGITS ARE ± 1%.
E EXPRESSED IN OHMS(Ω) ¼W ± 5%.
, OTHERWISE SPECIFIED

D-552104-C (REF)

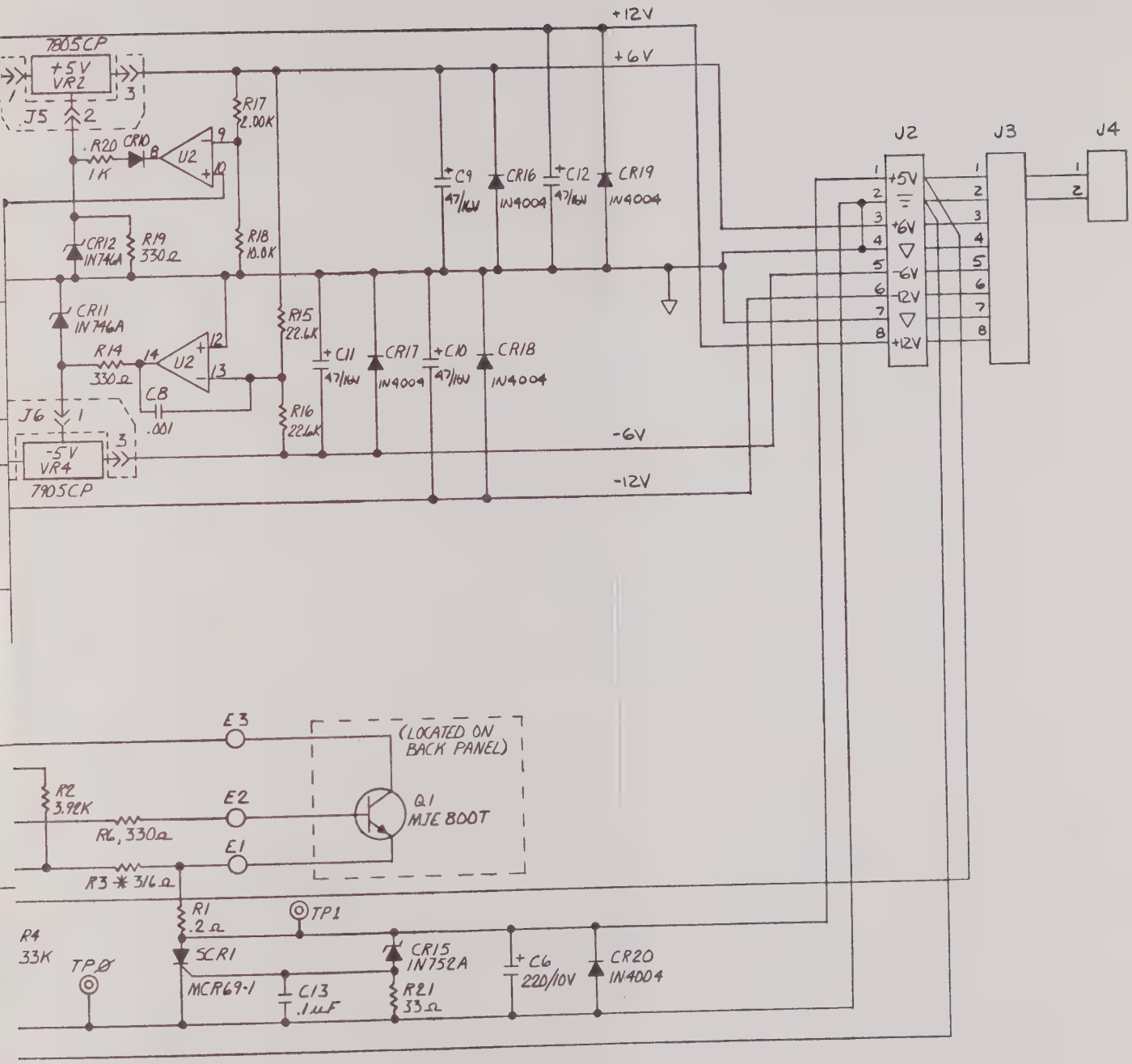
Figure 7-3. Schematic, Input Channel Conditioner



LAST REF DES.
R22
C13
CR20
Q1
U2
J8
E3
TP1
SCR1

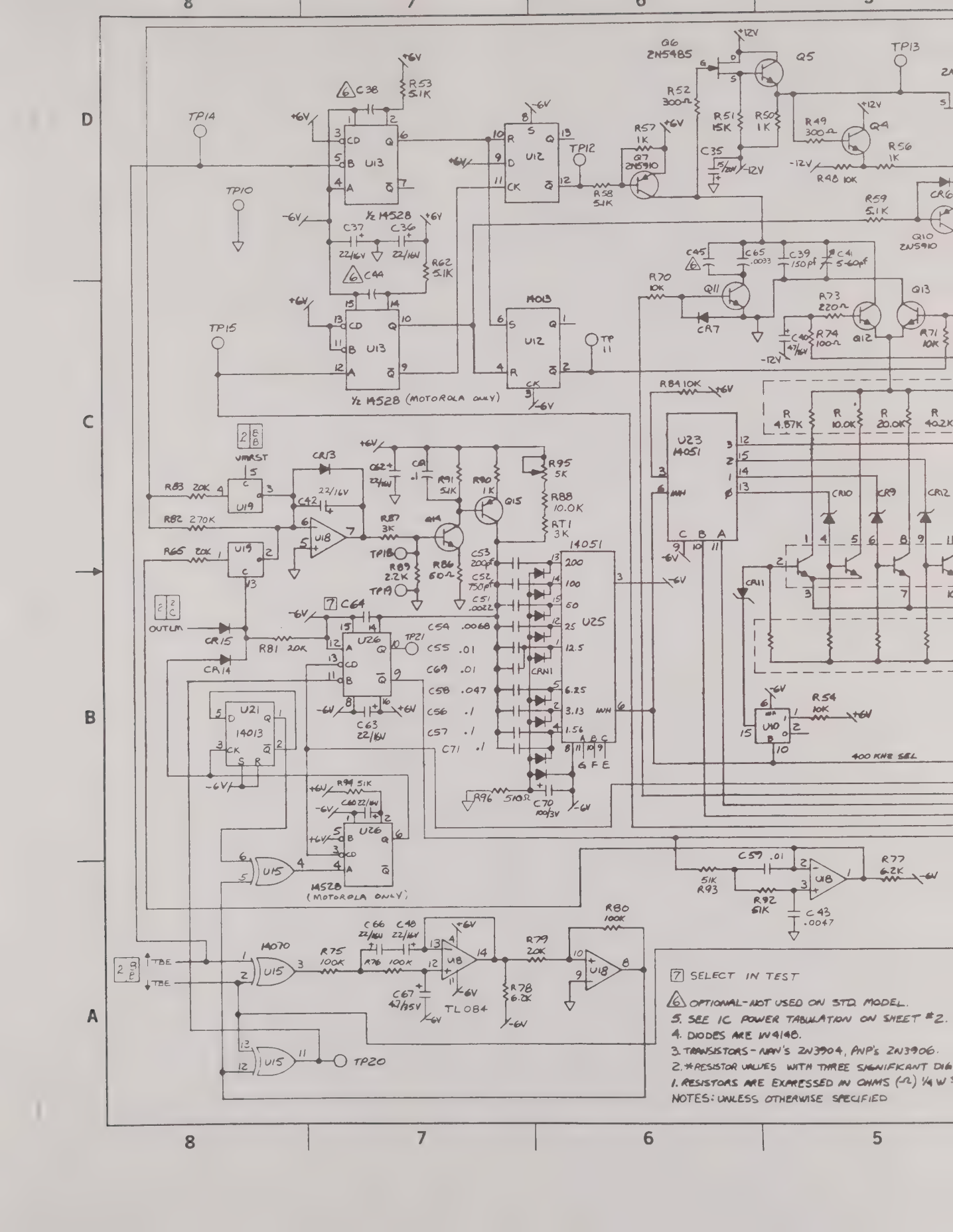
4. CAPACITOR VALUES ARE MICROFARADS
3. DIODES ARE IN4148.
2. *RESISTOR VALUES WITH THREE SIGNIFICANT DIGITS ARE ± 1%.
1. RESISTORS ARE EXPRESSED IN OHMS (Ω) 1/4 W ± 5%

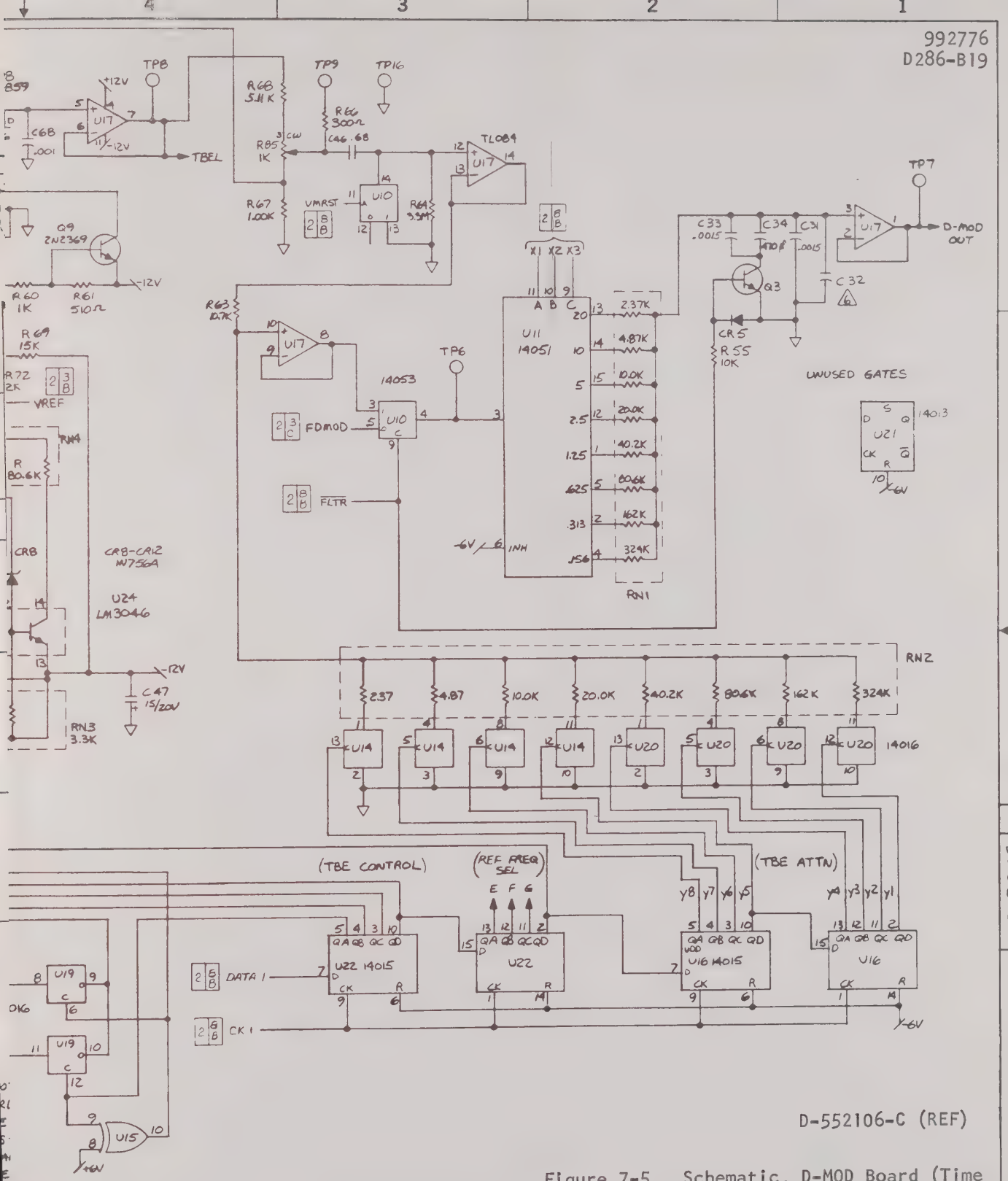
NOTES: UNLESS OTHERWISE SPECIFIED.



D-552105 (REF)

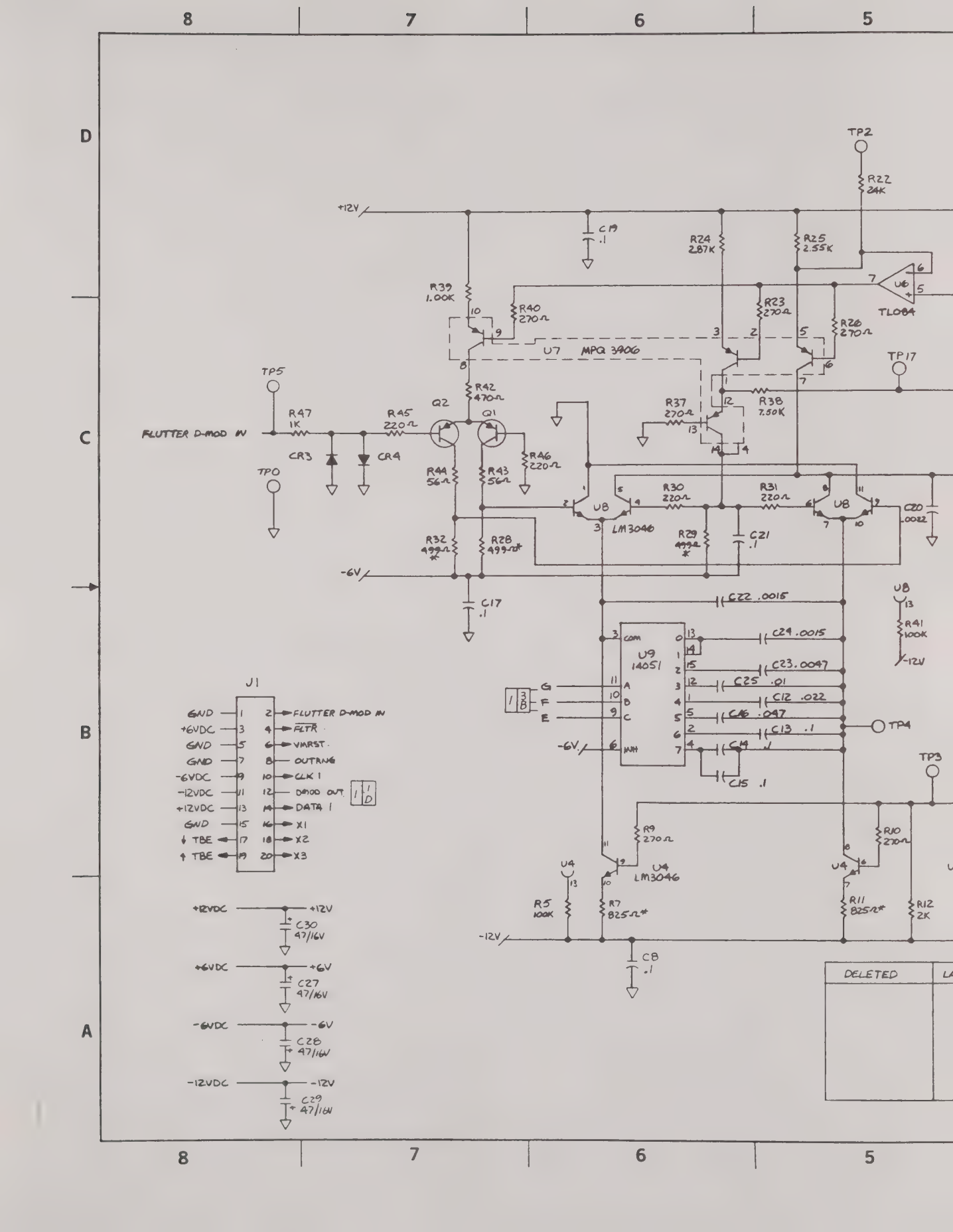
Figure 7-4. Schematic, Power Supply

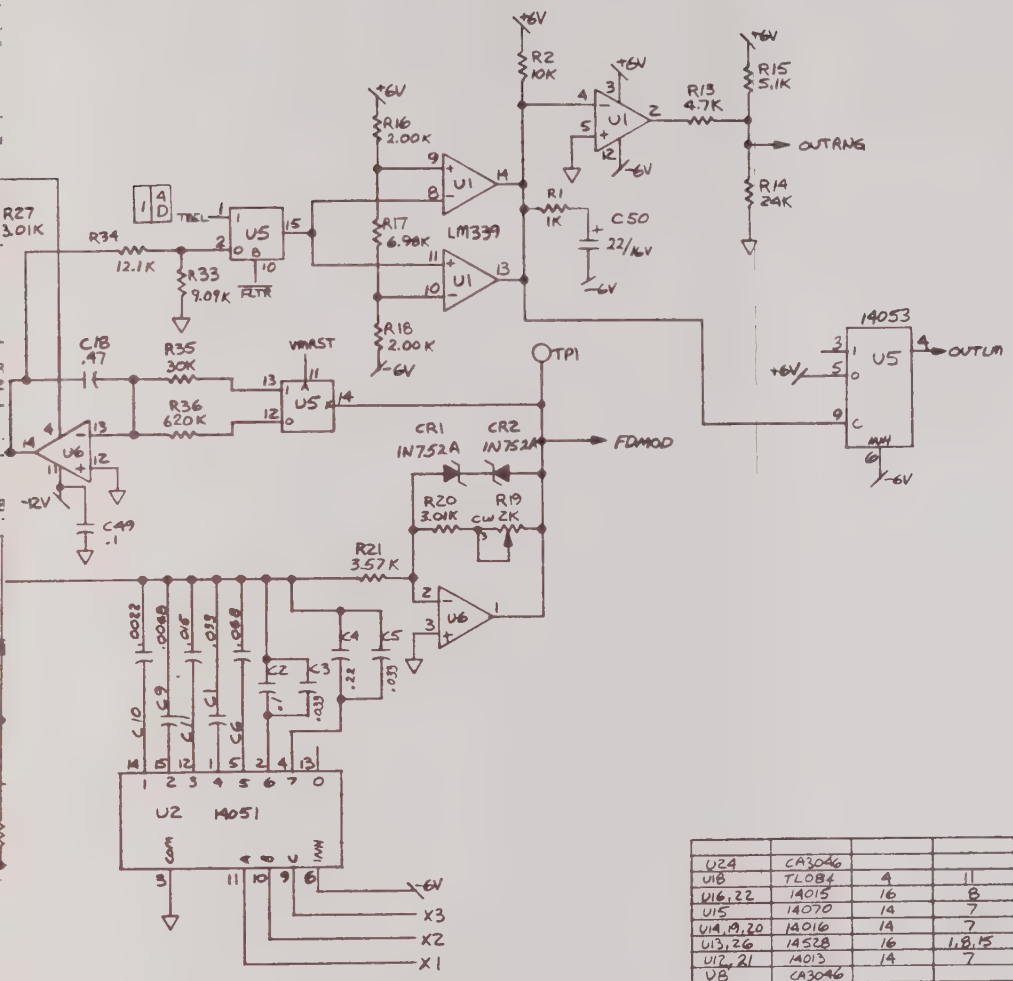

TP14
TP10
TP15
TP12
TP13
TP11
TP18
TP19
TP21
TP20
R53 5.1K
R52 300Ω
R51 15K
R50 1K
R49 300Ω
R48 10K
R56 1K
R57 1K
R58 5.1K
R59 5.1K
R62 5.1K
R70 10K
R71 10K
R73 220Ω
R74 100Ω
R80 100K
R83 20K
R82 270K
R85 20K
R81 20K
R84 10K
R87 3K
R88 10.0K
R89 2.2K
R86 60Ω
R90 1K
R91 5.1K
R95 5K
RT1 3K
R54 10K
R75 100K
R76 100K
R79 20K
R78 6.2K
R77 6.2K
R93 51K
R92 51K
R96 510Ω
R94 51K
C35 15/20V
C36 22/16V
C37 22/16V
C39 150pf
C41 5-60pf
C43 .0047
C45 .0033
C47 47/16V
C48 22/16V
C49 .1
C51 .0022
C52 750pf
C53 200pf
C54 .0068
C55 .01
C56 .1
C57 .1
C58 .047
C59 .01
C60 22/16V
C62 22/16V
C63 22/16V
C64
C65 .0033
C66 22/16V
C67 47/35V
C69 .01
C70 100/3V
C71 .1
C42 22/16V
Q5 2N5485
Q6 2N5485
Q7 2N5910
Q9
Q10 2N5910
Q11
Q12
Q13
Q15
CR3
CR7
CR9
CR10
CR11
CR12
CR13
CR14
CR15
CRN1
U8
U10
U12
U13
U15
U18
U19
U21 14013
U23 14051
U25
U26
½ 14528 (MOTOROLA ONLY)
14051
14070
TL084
VMRST
OUTLM
400 KHz SEL
+12V
-12V
+6V
-6V
7 SELECT IN TEST
6 OPTIONAL-NOT USED ON STD MODEL.
5. SEE IC POWER TABULATION ON SHEET #2.
4. DIODES ARE IN4148.
3. TRANSISTORS - NPN's 2N3904, PNP's 2N3906.
2. *RESISTOR VALUES WITH THREE SIGNIFICANT DIG
1. RESISTORS ARE EXPRESSED IN OHMS (Ω) 1/4 W
NOTES: UNLESS OTHERWISE SPECIFIED

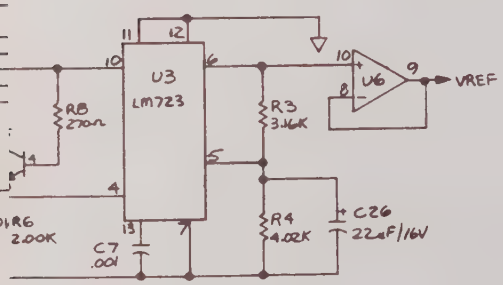


D-552106-C (REF)

Figure 7-5. Schematic, D-MOD Board (Time Base) (Sheet 1 of 2)


TP2
R22 24K
+12V
C19 .1
R24 2.87K
R25 2.55K
R39 1.00K
R40 270Ω
U6
TL084
R23 270Ω
R26 270Ω
U7 MPQ 3906
TP17
TP5
R42 470Ω
Q2
Q1
R37 270Ω
R38 7.50K
FLUTTER D-MOD IN
R47 1K
R45 220Ω
CR3
CR4
R46 220Ω
TP0
R44 56Ω
R43 56Ω
U8
LM3046
R30 220Ω
R31 220Ω
C20 .0022
R32 499Ω*
R28 499Ω*
R29 499Ω*
C21 .1
-6V
C17 .1
C22 .0015
U8
R41 100K
-12V
U9 14051
C24 .0015
C23 .0047
C25 .01
C12 .022
C16 .047
C13 .1
C14 .1
C15 .1
TP4
TP3
J1
GND
+6VDC
GND
GND
-6VDC
-12VDC
+12VDC
GND
TBE
TBE
FLUTTER D-MOD IN
FLTR
VMRST
OUTRNG
CLK 1
DMOD OUT
DATA 1
X1
X2
X3
R9 270Ω
R10 270Ω
U4
LM3046
R5 100K
R7 825Ω*
R11 825Ω*
R12 2K
C8 .1
+12VDC
C30 47/16V
+6VDC
C27 47/16V
-6VDC
C28 47/16V
-12VDC
C29 47/16V
DELETED





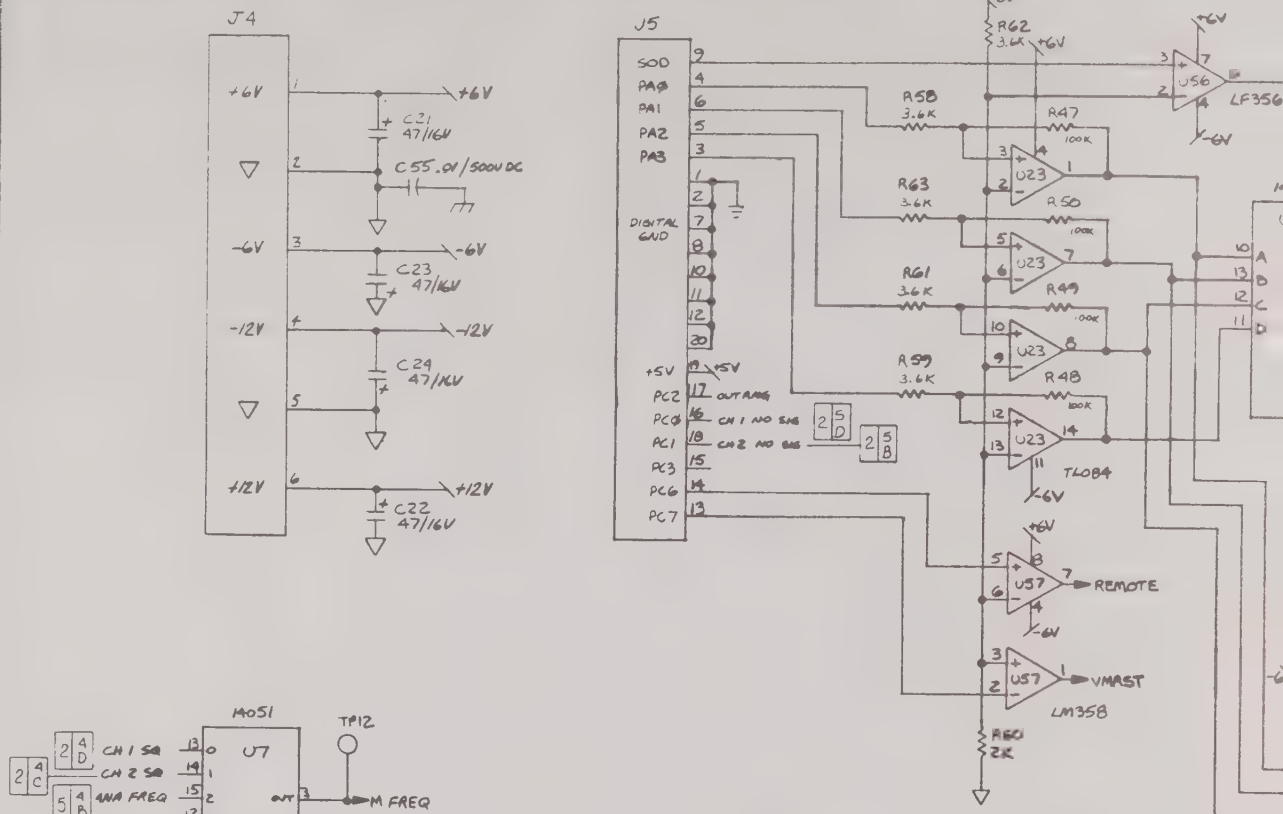
U24	CA3046					3,7,10,13
U18	TL084	4	11			
U16,22	14015	16	8			
U15	14070	14	7			
U14,19,20	14016	14	7			
U13,26	14528	16	1,8,15			
U12,21	14013	14	7			
U8	CA3046			1,11		
U7	MAB3906					
U6,U17	TL084				4	11
U5,U10	14053	16	7,8			
U4	CA3046					
U3	LM723			11,12		7
U2,9,11,23,25	14051	16	7,8			
U1	LM339	3	12			
REF	PART #	+6V	-6V	GND	+12V	-12V

IC POWER TABULATION

T REF DES	
U26	U1
R96	RT1
CR15	CR11
C71	
Q15	
RN4	
TP21	

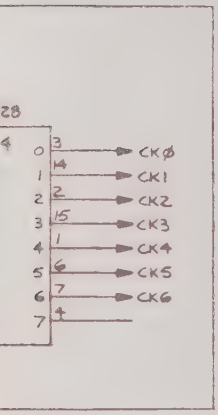
D-552106-C (REF)

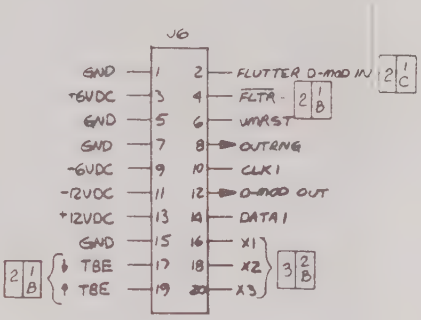
Figure 7-5. Schematic, D-MOD Board (Flutter) (Sheet 2 of 2)

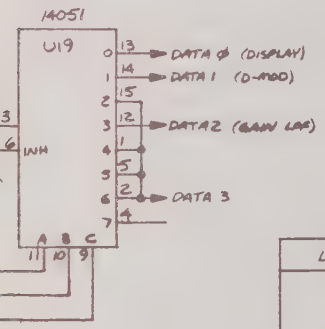


NOTES: UNLESS OTHERWISE SPECIFIED

1. RESISTOR VALUES ARE EXPRESSED IN OHMS
2. *RESISTOR VALUES WITH THREE SIGNIFICANT
3. TRANSISTORS - NPN's 2N3904, PNP's 2N39
4. DIODES ARE 1N4148.
5. SEE IC POWER TABULATION CHART ON SHT 1.
6. OPTIONAL, NOT USED ON STD.
7. MATCHED SET.







LAST REF
R178 Q18 C56 CR28 U57 J8 TP25 RN4 VR1 E16 BD1 RT1

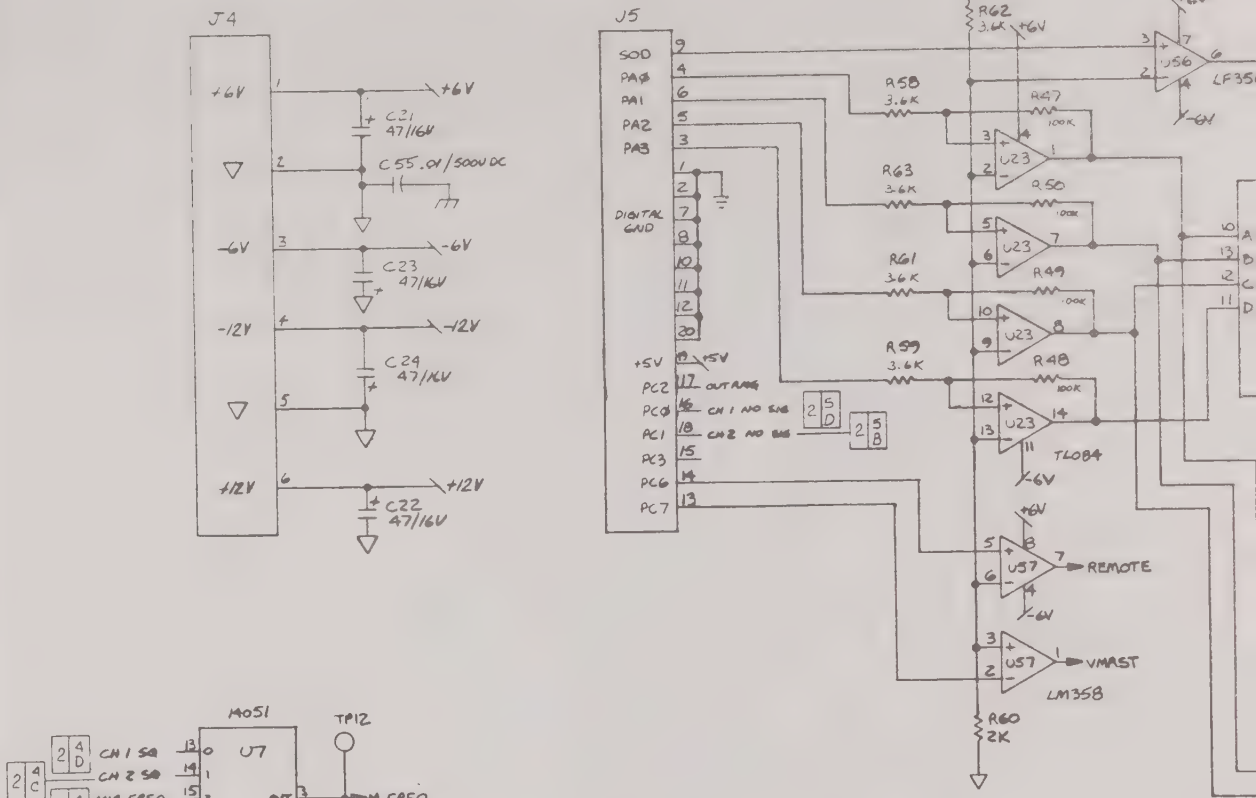
DELETED
C5 R74 CR13 Q7 R157 R11-18 R1 R2

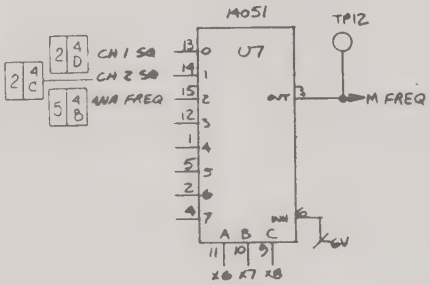
U#	PART#	+6V	-6V	+12V	-12V	+5V	⏚GND	▽GND
57	TL082	8	4					
47	LM358	8	4					
56	LF356	7	4					
54	14013	14	7					
53	14040	16	8					
46,50	LM339	3			12			
43	ADC0804					20	10	8
41	14528	16	8					
40	14053	16	7,8					
32	14518	16	8					
33,29,30,61	TL084			4	11			
27	14046	16	8					
24	LF356	7			4			
18	DAC0808	13			3			1,2
17,23,48	TL084	4	11					
16,52	14011	14	7					
15	14027	16	8					
14	14028	16	8					
13	140948	16	8					
12	14001	14	7					
11,21	140668	14	7					
7,19,36,37,38,39,44,55	14051	16	7,8					
6	14025	14	7					
5,8,10,33,42	14015	16	8					
4,9,20,22,29,31,34	14052	16	7,8					
2,35	14049	1	8					
1,3,24,45,49	14016	14	7					

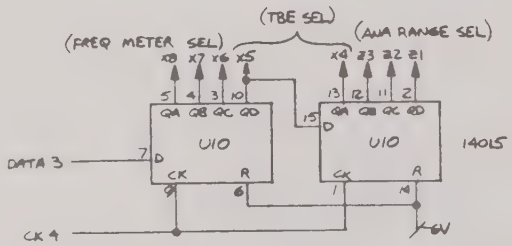
IC POWER TABULATION CHART

D-552107-B (REF)

Figure 7-6. Schematic, Interconnect Board (Sheet 1 of 5)

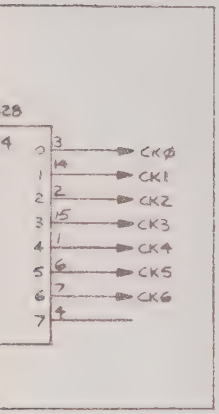


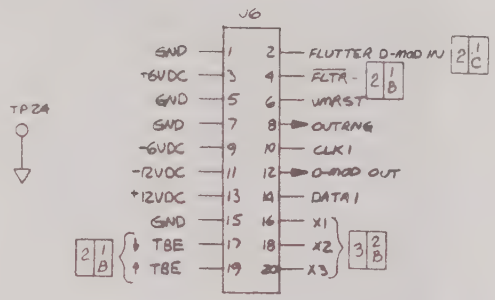


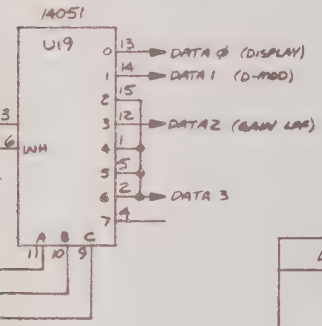


NOTES: UNLESS OTHERWISE SPECIFIED

1. RESISTOR VALUES ARE EXPRESSED IN O
2. *RESISTOR VALUES WITH THREE SIGNIF
3. TRANSISTORS - NPN's 2N3904, PNP's
4. DIODES ARE 1N4148.
5. SEE IC POWER TABULATION CHART ON S
6. OPTIONAL, NOT USED ON ST
7. MATCHED SET.







LAST REF
R178
Q18
C56
CR28
U57
J8
TP25
RN4
VR1
E16
BD1
RT1

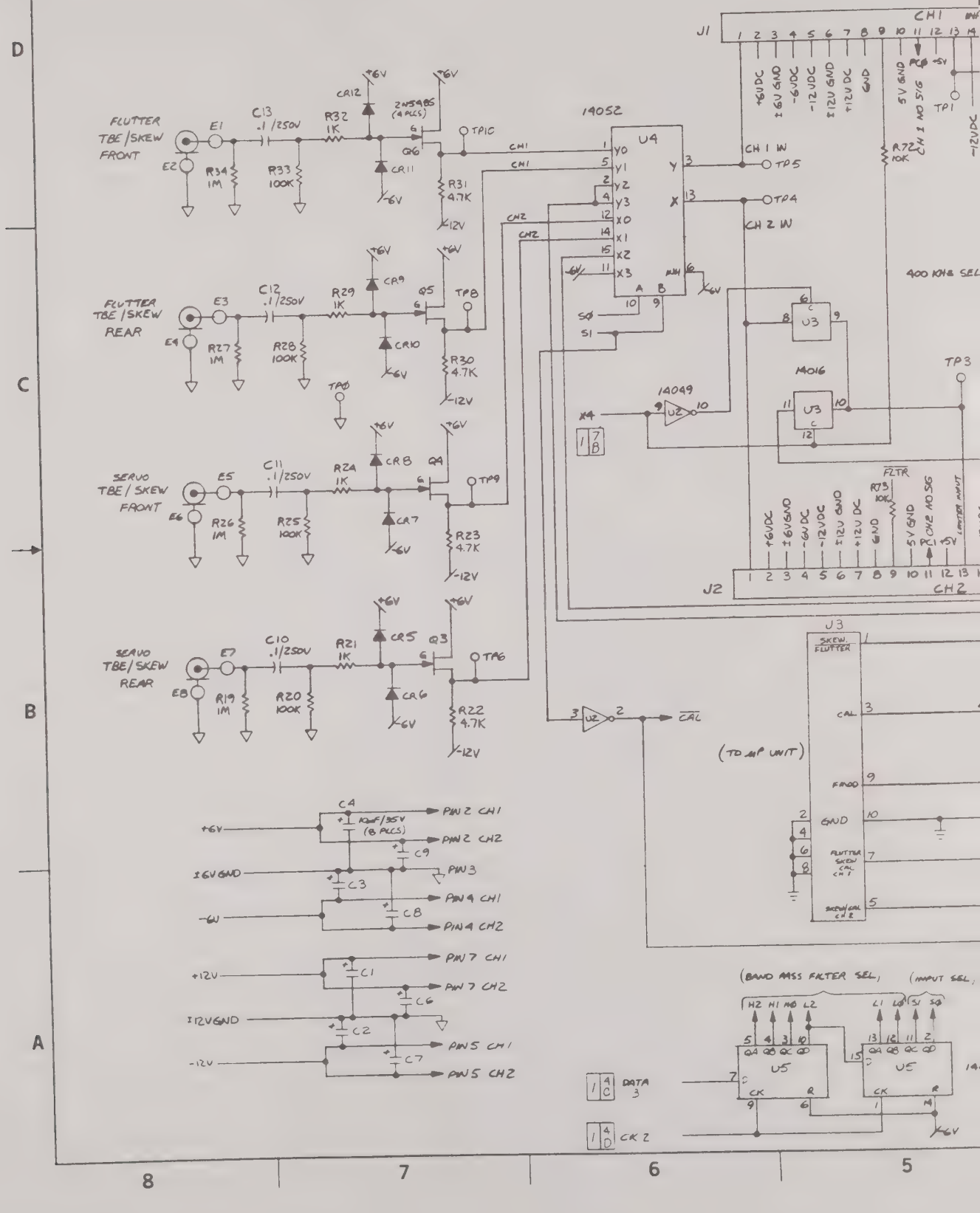
DELETED
C5
R74
CR13
Q7
R157
R11-18
R1
R2

U#	PART #	+6V	-6V	+12V	-12V	+5V	⏚ GND	▽ GND
57	TL082	8	4					
47	LM358	8	4					
56	LF356	7	4					
54	14013	14	7					
53	14040	16	8					
46,50	LM339	3			12			
43	ADC0804					20	10	8
41	14528	16	8					
40	14053	16	7,8					
32	14518	16	8					
3,29,30,61	TL084			4	11			
27	14046	16	8					
24	LF356	7			4			
18	DAC0808	13			3			1,2
17,23,48	TL084	4	11					
16,52	14011	14	7					
15	14027	16	8					
14	14028	16	8					
13	140948	16	8					
12	14001	14	7					
11,21	140668	14	7					
7,19,36,37,38 39,44,55	14051	16	7,8					
6	14025	14	7					
5,8,10,33,42	14015	16	8					
4,9,20,22,29 31,34	14052	16	7,8					
2,35	14049	1	8					
1,3,26,45 49	14016	14	7					

IC POWER TABULATION CHART

D-552107-B (REF)

Figure 7-6. Schematic, Interconnect Board (Sheet 1 of 5)


8
7
6
5
D
C
B
A
FLUTTER TBE/SKEW FRONT
E1
E2
C13 .1/250V
R32 1K
R34 1M
R33 100K
CR12
2N5985 (4 PLCS)
Q6
CR11
TP10
R31 4.7K
+6V
-6V
+12V
FLUTTER TBE/SKEW REAR
E3
E4
C12 .1/250V
R29 1K
R27 1M
R28 100K
CR9
Q5
CR10
TP8
R30 4.7K
TP0
SERVO TBE/SKEW FRONT
E5
E6
C11 .1/250V
R24 1K
R26 1M
R25 100K
CR8
Q4
CR7
TP9
R23 4.7K
SERVO TBE/SKEW REAR
E7
E8
C10 .1/250V
R21 1K
R19 1M
R20 100K
CR5
Q3
CR6
TP6
R22 4.7K
CH1
CH2
14052
U4
Y0
Y1
Y2
Y3
X0
X1
X2
X3
A
B
S0
S1
CH 1 W
CH 2 W
TP5
TP4
400 KHz SEL
14016
U3
14049
U2
X4
TP3
J1
J2
+6VDC
+6V GND
-6VDC
-12VDC
+12V GND
+12V DC
GND
5V GND
CH 1 NO SIG
CH 2 NO SIG
+5V
-12VDC
FLTR
R73 10K
CENTER INPUT
U3
SKEW/FLUTTER
CAL
FROM
GND
FLUTTER SKEW CH 1
SKEW/CAL CH 2
(TO MP UNIT)
C4 10uF/35V (8 PLCS)
C9
C3
C8
C1
C6
C2
C7
PIN 2 CH1
PIN 2 CH2
PIN 3
PIN 4 CH1
PIN 4 CH2
PIN 7 CH1
PIN 7 CH2
PIN 5 CH1
PIN 5 CH2
+6V
+6V GND
-6V
+12V
+12V GND
-12V
(BAND PASS FILTER SEL)
(INPUT SEL)
H2
H1
H0
L2
L1
L0
S1
S0
U5
CK
Q
DATA 3
CK 2

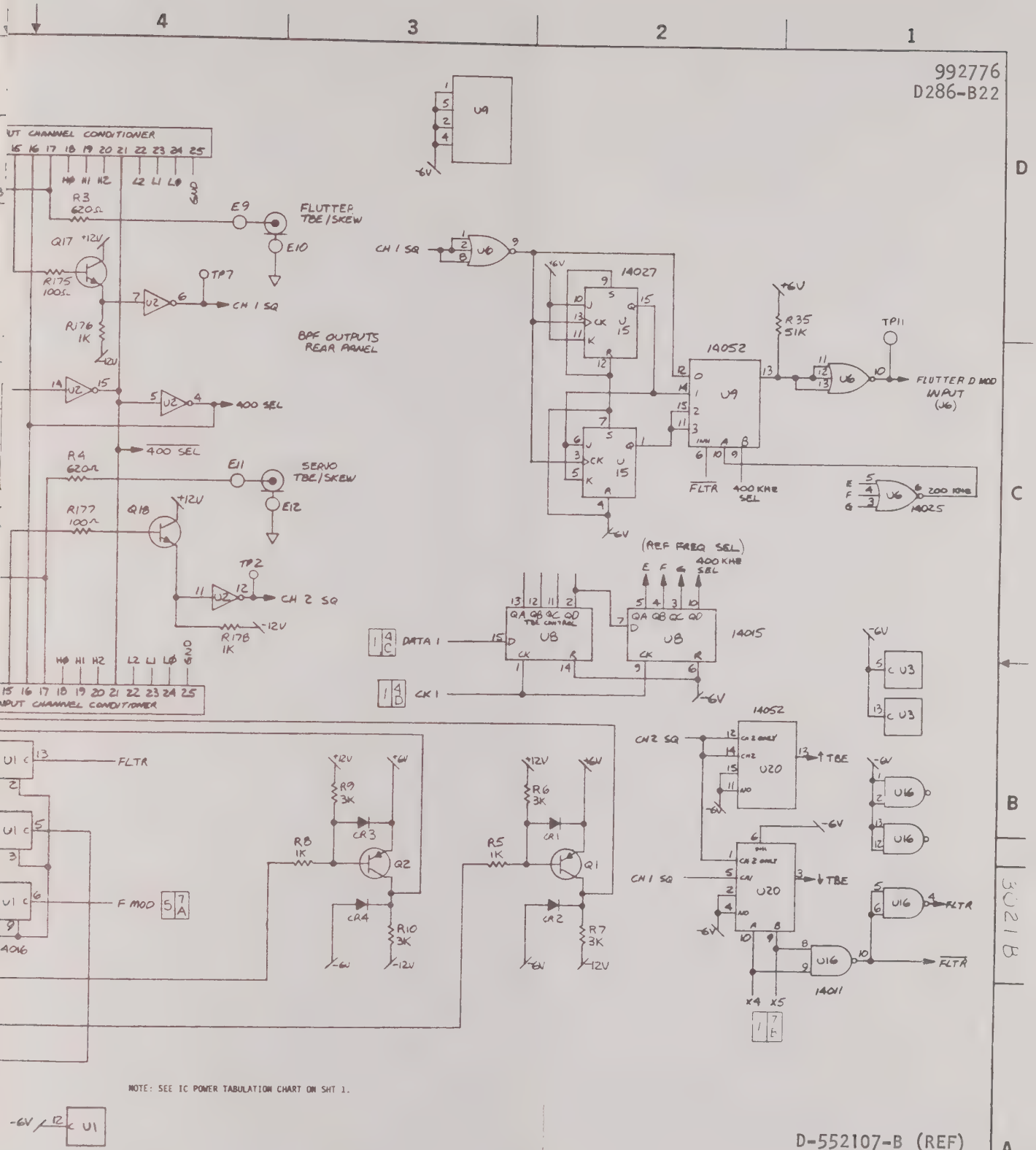
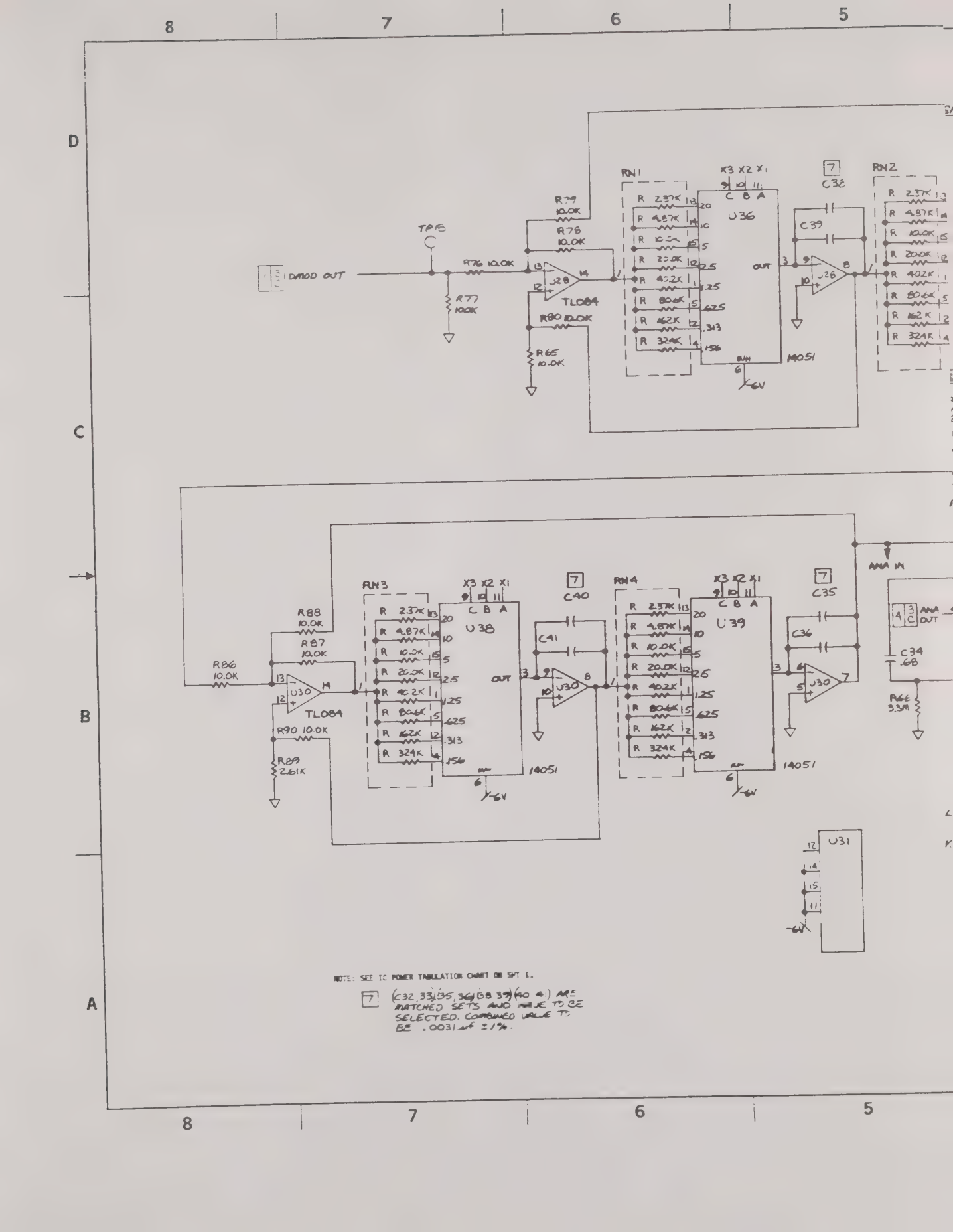
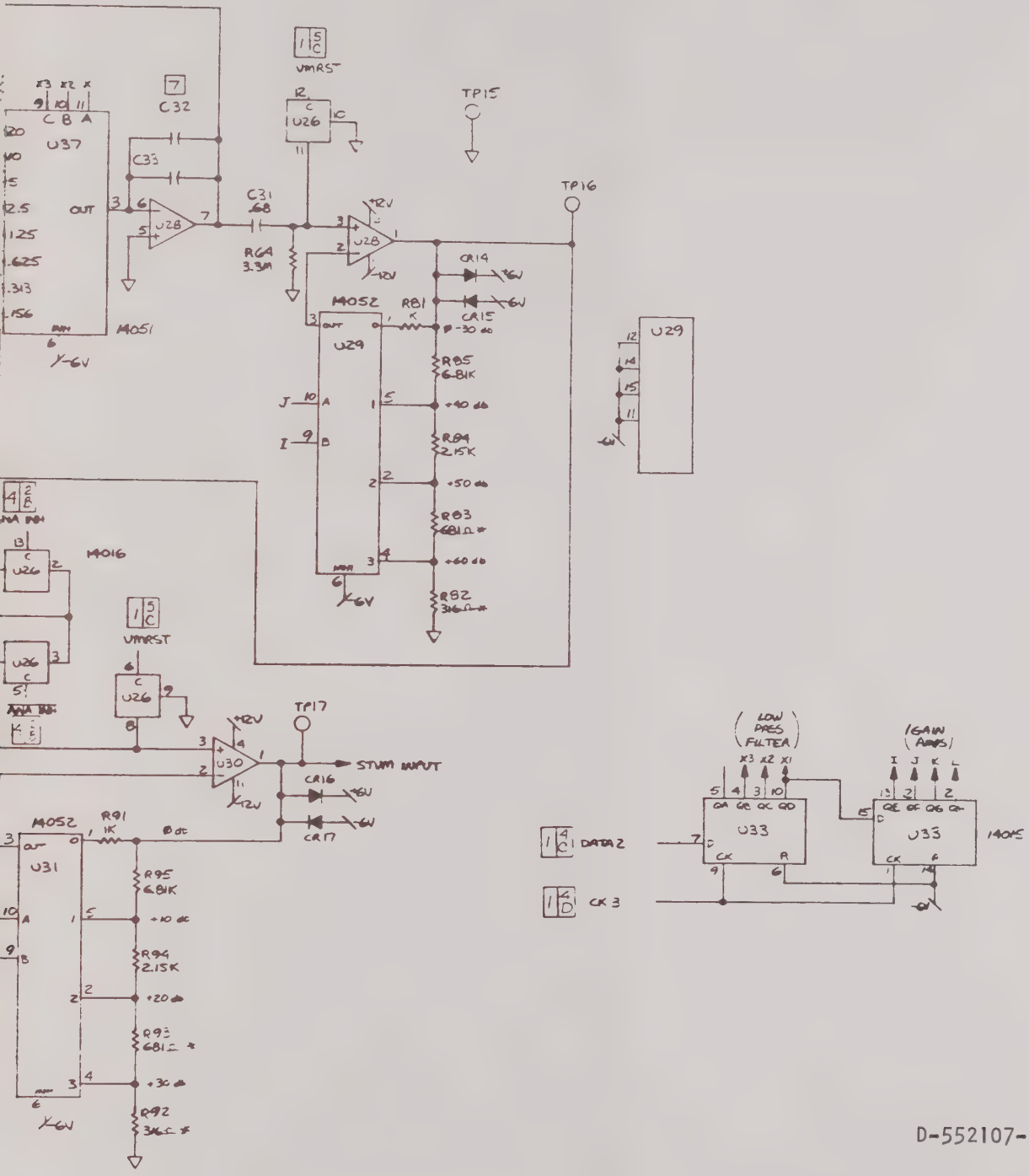


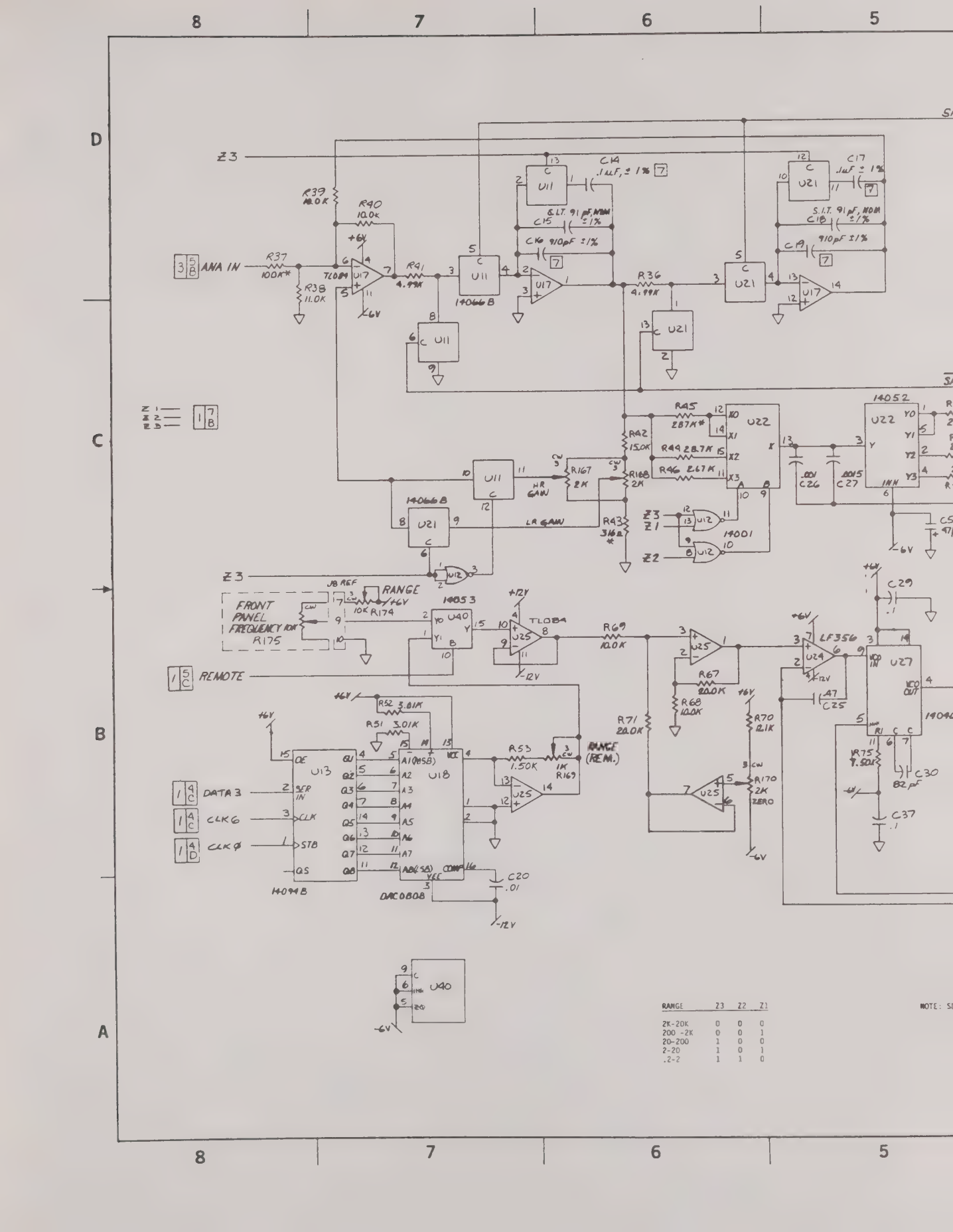
Figure 7-6. Schematic, Interconnect Board (Sheet 2 of 5)

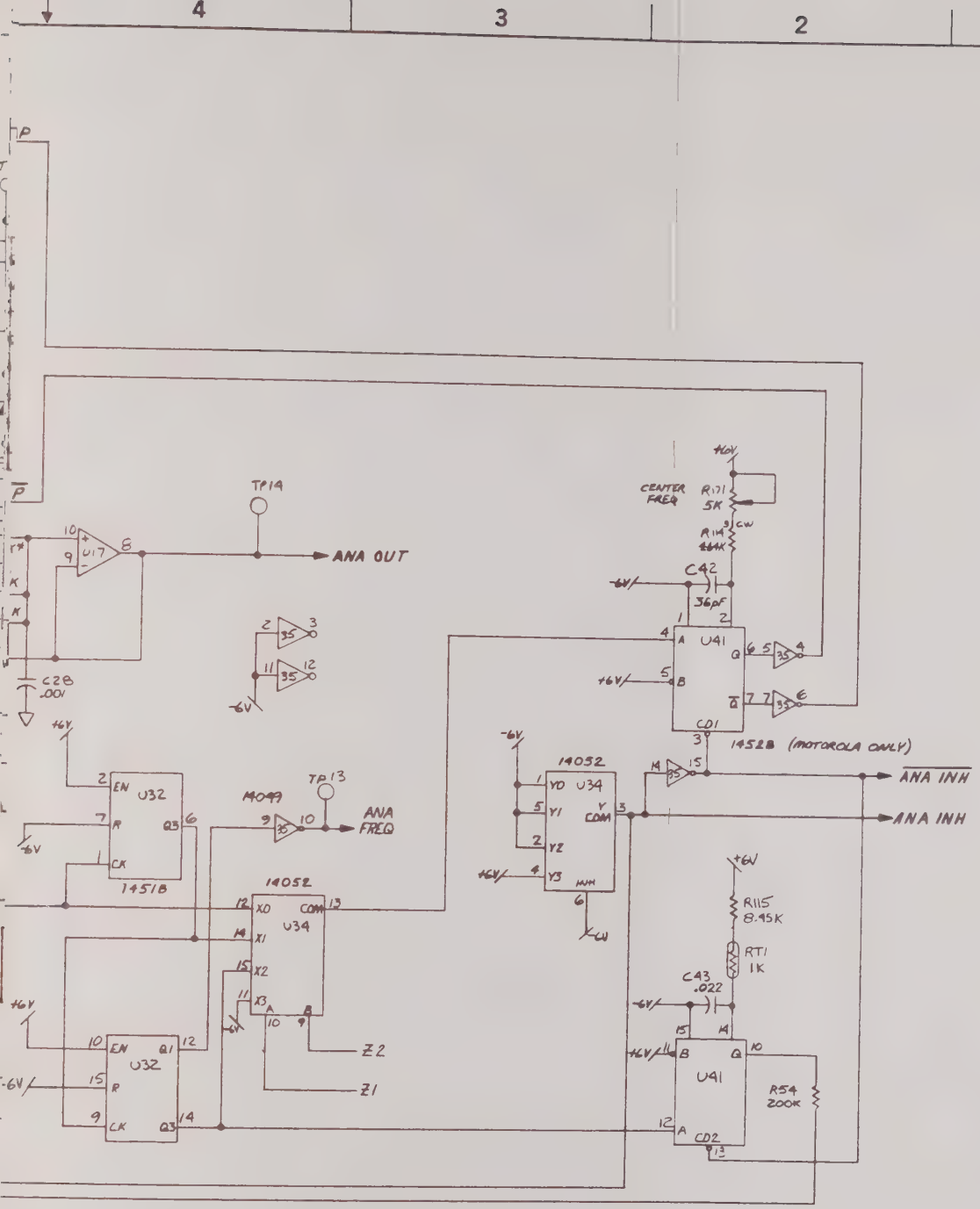

8
7
6
5
D
C
B
A
DMOD OUT
TP15
R76 10.0K
R77 100K
R79 10.0K
R78 10.0K
R80 10.0K
R65 10.0K
U28
TL084
RN1
U36
X3 X2 X1
C B A
14051
C38
C39
U26
RN2
R 2.37K
R 4.87K
R 10.0K
R 20.0K
R 40.2K
R 80.6K
R 162K
R 324K
-6V
R86 10.0K
R87 10.0K
R88 10.0K
R89 2.61K
R90 10.0K
U30
RN3
U38
C40
C41
RN4
U39
C35
C36
C34 .68
R66 5.36K
ANA IN
ANA OUT
U31
NOTE: SEE IC POWER TABULATION CHART ON SHT 1.
7 (C32, 33, 35, 36, 38, 39, 40, 41) ARE MATCHED SETS AND MUST BE SELECTED. COMBINED VALUE TO BE .0031 uF ± 1%.



D-552107-B (REF)

Figure 7-6. Schematic, Interconnect Board (Sheet 3 of 5)

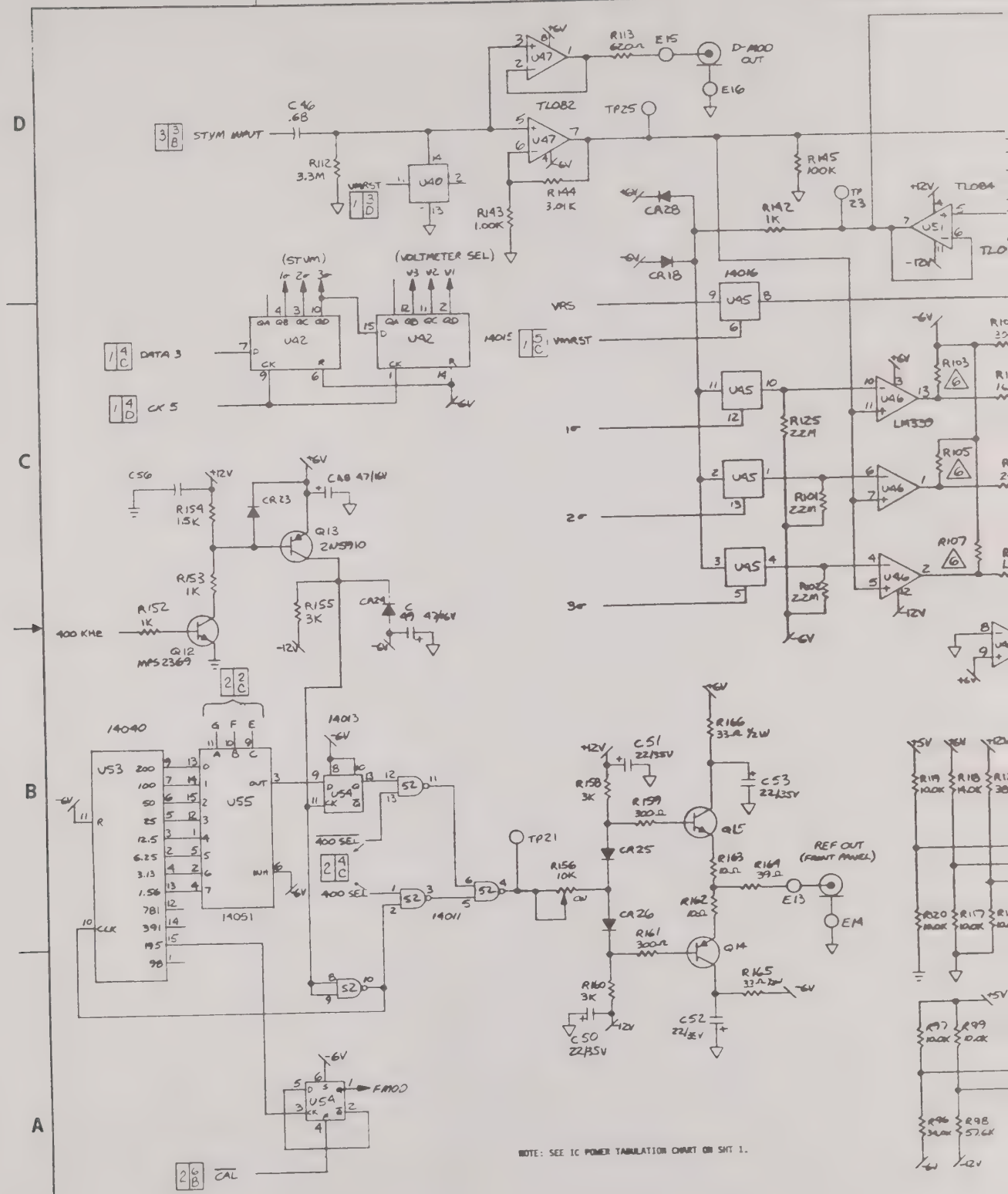

Z3
ANA IN
R37 100K*
R38 11.0K
R39 10.0K
R40 10.0K
R41 4.99K
R36 4.99K
TL084
U17
U11
U21
14066B
C14 .1uF, ± 1%
C15 S.L.T. 91 pF, NOM ± 1%
C16 910pF ± 1%
C17 .1uF ± 1%
C18 S.L.T. 91 pF, NOM ± 1%
C19 910pF ± 1%
+6V
-6V
R45 287K*
R42 150K
R49 28.7K
R46 2.67K
U22
14052
R167 2K
R168 2K
HR GAIN
LR GAIN
R43 316K*
14001
U12
C26 .001
C27 .0015
.1MH
C28
Z1
Z2
Z3
JB REF
RANGE
FRONT PANEL FREQUENCY ADJ
R175
R174 10K
14053
U40
TL084
U25
+12V
-12V
R69 10.0K
REMOTE
R67 20.0K
R68 10.0K
R71 20.0K
R70 2.1K
R170 2K ZERO
LF356
U24
C29 .1
C25 .47
U27
VCO IN
VCO OUT
14046
R175 7.50K
C30 82pF
C37 .1
R52 3.81K
R51 3.01K
R53 1.50K
R169 1K
RANGE (REM.)
DATA 3
CLK 6
CLK Ø
U13
U18
14094B
DAC0808
C20 .01
RANGE Z3 Z2 Z1
2K-20K 0 0 0
200 -2K 0 0 1
20-200 1 0 0
2-20 1 0 1
.2-2 1 1 0
NOTE: S



POWER TABULATION CHART ON SHT 1.

D-552107-B (REF)

Figure 7-6. Schematic, Interconnect Board (Sheet 4 of 5)


8
7
6
5
D
C
B
A
U47
TL082
R113 620Ω
E15
D-MOD OUT
E16
TP25
C46 .68
STYM INPUT
R112 3.3M
VARRST
U40
R143 1.00K
R144 3.01K
R145 100K
R142 1K
TP 23
CR28
CR18
+12V
TL084
U51
-12V
(STYM)
(VOLTMETER SEL)
U42
14016
U45
VRS
VARRST
DATA 3
CK 5
U46
LM339
R103
R125 22M
R105
R101 22M
R107
R102 22M
+6V
-6V
C56
CR23
CR24
C48 47/16V
R154 1.5K
Q13 2N5910
R153 1K
R152 1K
400 KHz
Q12 MPS2369
R155 3K
C49 47/16V
14040
U53
U55
14051
14013
U54
400 SEL
14011
S2
TP21
R156 10K
C51 22/35V
R158 3K
R159 300Ω
Q15
CR25
CR26
R161 300Ω
Q14
R160 3K
C50 22/35V
C52 22/35V
R166 33Ω ½W
C53 22/35V
R163 10Ω
R169 39Ω
R162 10Ω
R165 33Ω ½W
REF OUT (FRONT PANEL)
E13
EM
R119 10.0K
R118 14.0K
R120 10.0K
R117 10.0K
R97 10.0K
R99 10.0K
R96 34.0K
R98 57.6K
FMOD
CAL
NOTE: SEE IC POWER TABULATION CHART ON SHT 1.

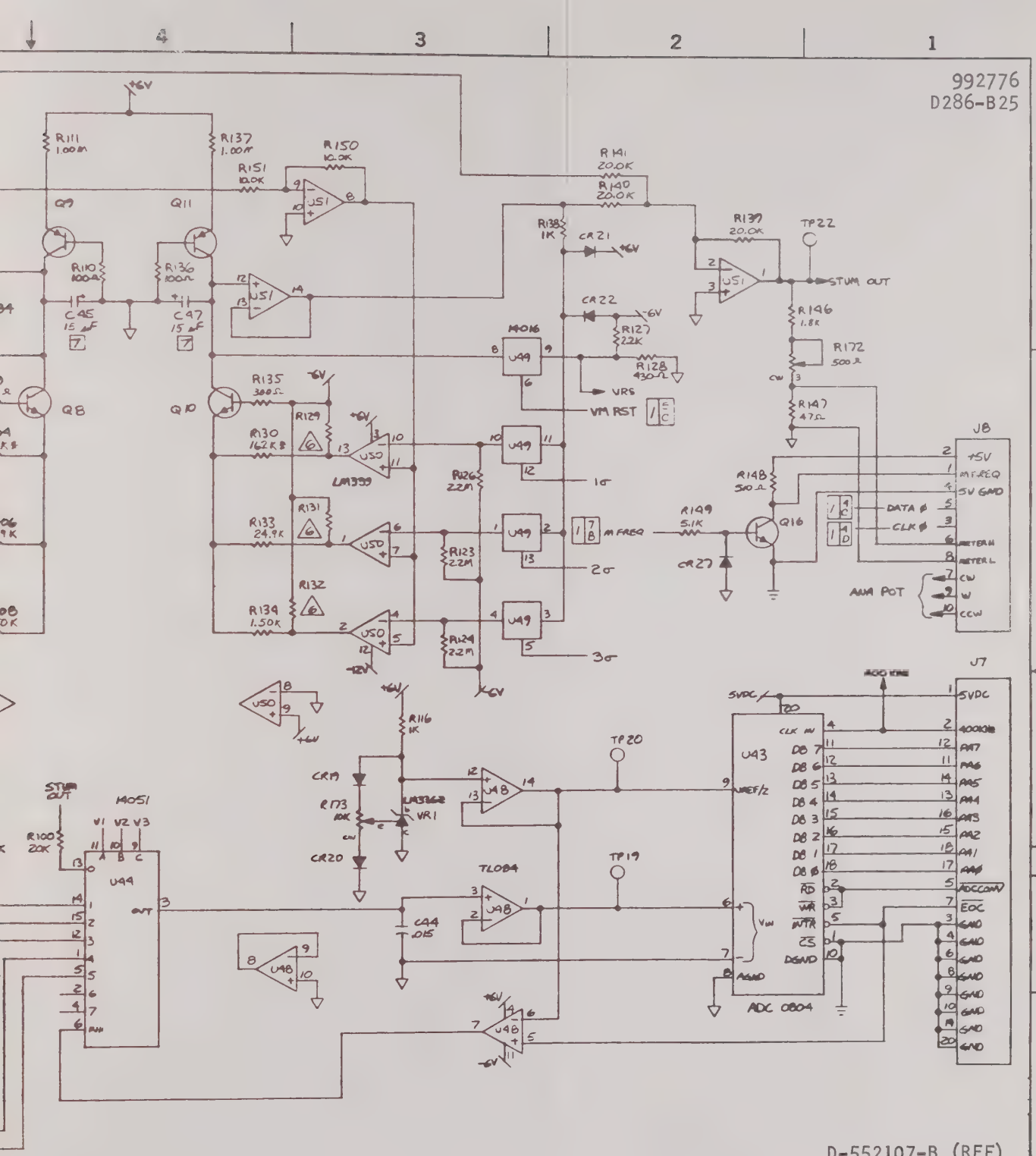
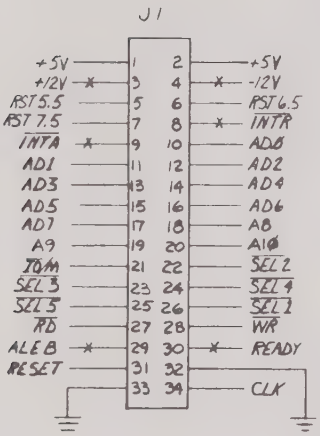
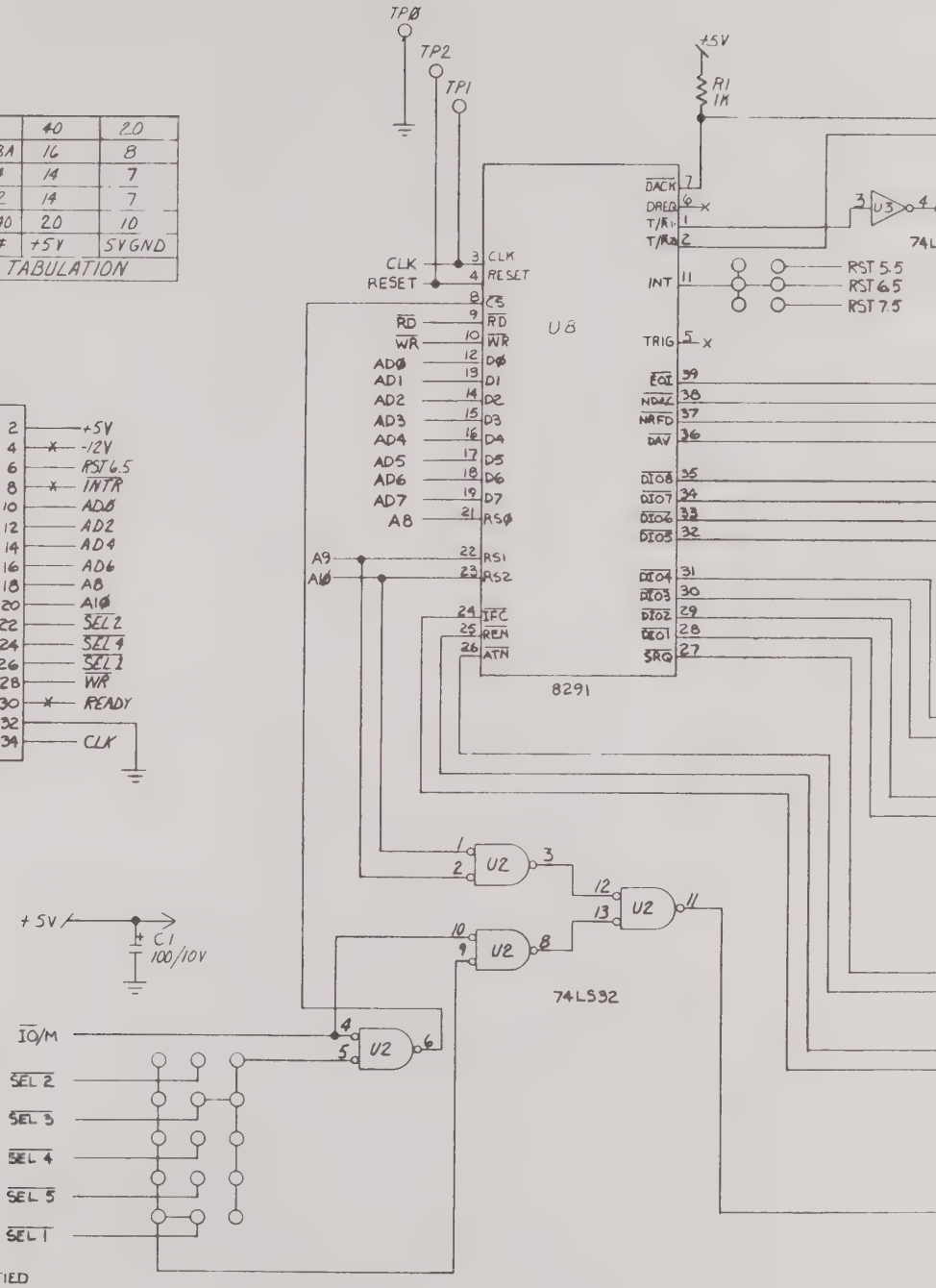


Figure 7-6. Schematic, Interconnect Board (Sheet 5 of 5)

U8	8291	40	20
U4-U7	MC3448A	16	8
U3	74LS04	14	7
U2	74LS32	14	7
U1	74LS240	20	10
REF	PART #	+5V	5V GND

IC POWER TABULATION



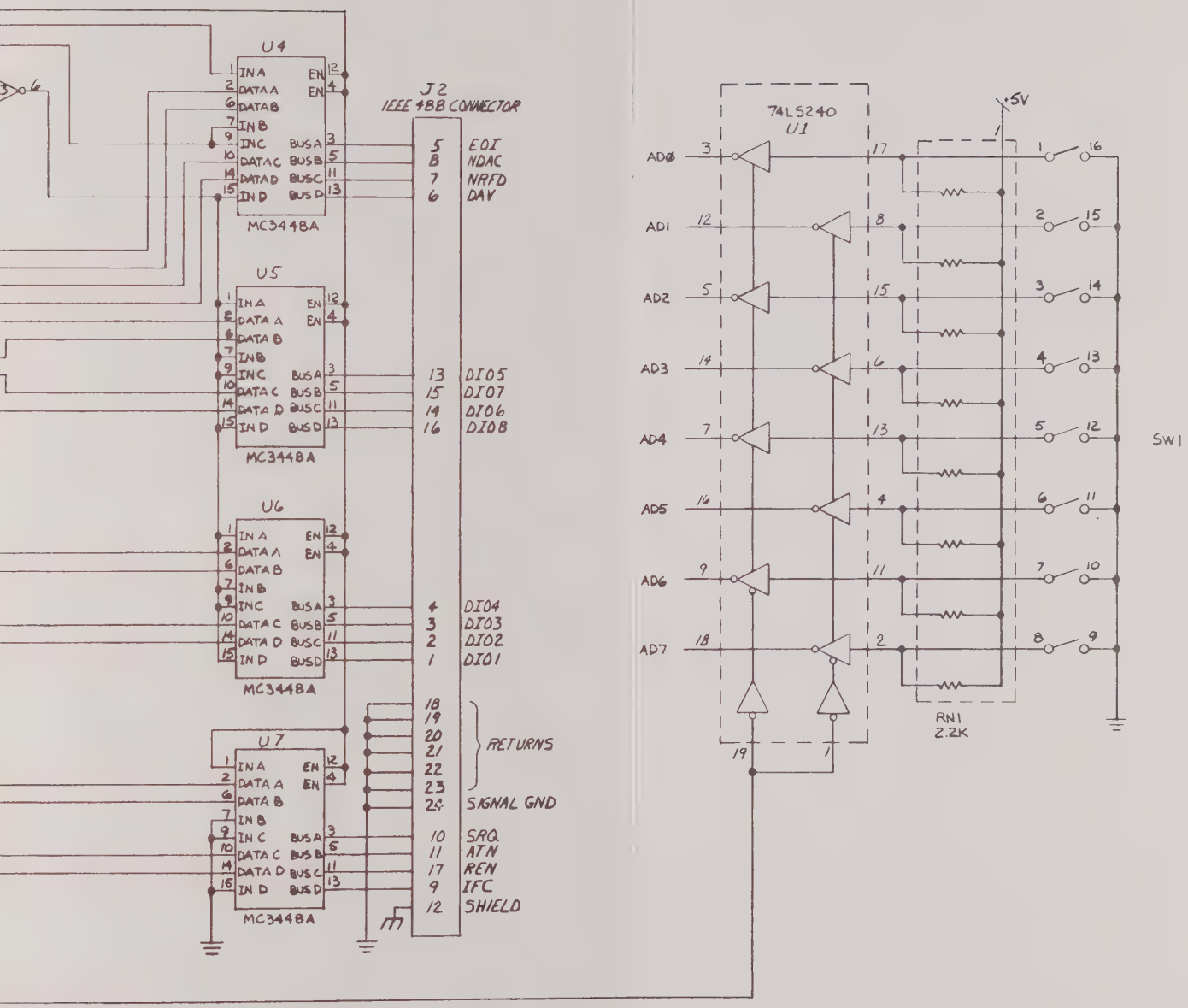


NOTES. UNLESS OTHERWISE SPECIFIED

1. RESISTORS ARE EXPRESSED IN OHMS (Ω), W, ± 5%.
2. *RESISTOR VALUES WITH THREE SIGNIFICANT DIGITS ARE ± 1%.
3. TRANSISTORS - NPN'S 2N3904, PNP'S 2N3906
4. DIODES ARE 1N4148.
5. CAPACITANCE IS IN MICROFARADS

+5V

UNUSE

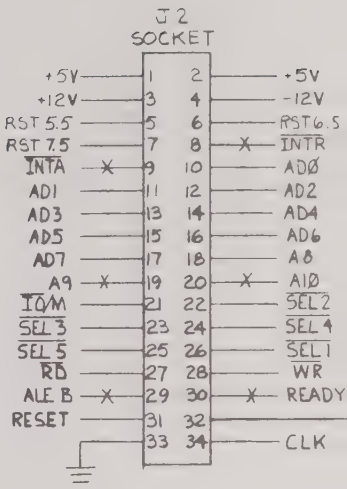


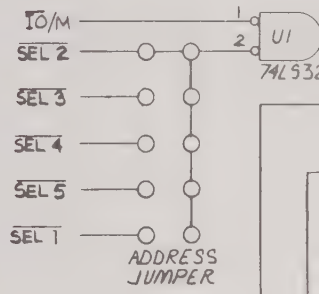
D-552108 (REF)

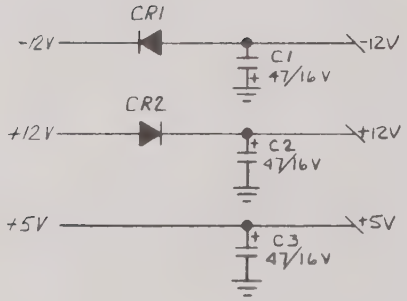
Figure 7-7. Schematic, IEEE 488 Interface

300	O	C	O	C	4.80
1200	O	O	O	C	19.2
2400	C	O	C	O	38.4
4800	C	C	O	O	76.8
9600	C	O	O	O	153.6
BAUD RATE	SWIA	SWIB	SWIC	SWID	TPI, KHz

U5	MC1489	14	7		
U4	MC1488		7	14	1
U3	WD1943	2	11		
U2	8251A	26	4		
U1	74LS32	14	7		
REF #	PART #	+5V	GND	+12V	-12V
IC POWER TABULATION					



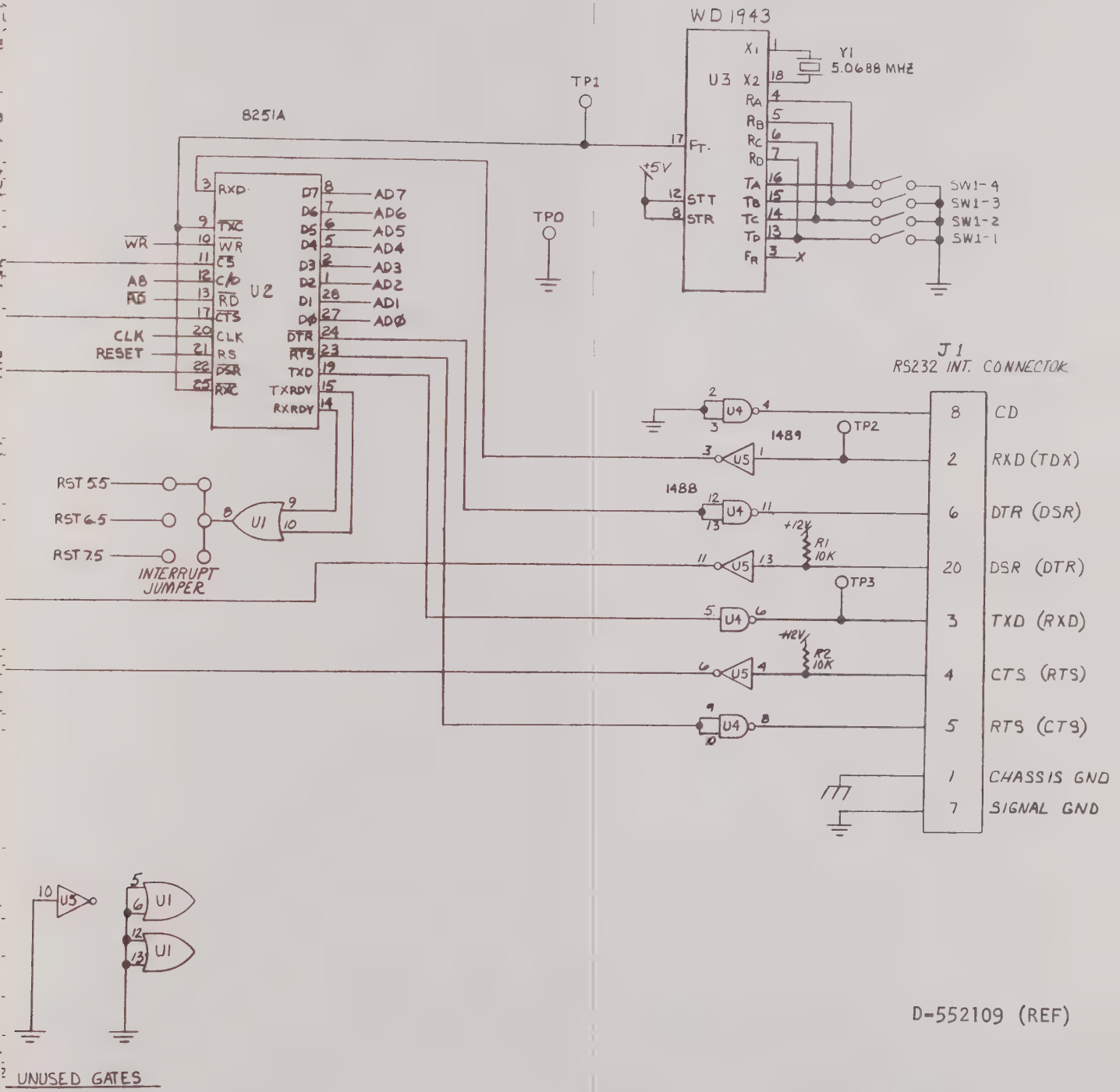




LAST REF DES
U5 R2 CR2 C3 J2 TP3 Y1
DELETED

6. ADDITIONL BAUD RATES CAN BE SELECTED.
5. CAPACITOR VALUES ARE IN MICROFARADS.
4. DIODES ARE IN4148.
3. TRANSISTORS - NPN'S 2N3904 PNP'S 2N3906
2. * RESISTOR VALUES WITH THREE SIGNIFICANT DIGITS ARE ±1%.
1. RESISTORS ARE EXPRESSED IN OHMS(Ω)V4W ±5%

NOTES: UNLESS OTHERWISE SPECIFIED.



D-552109 (REF)

Figure 7-8. Schematic, RS-232C Interface

SECTION VIII

REMOTE CONTROL OPTIONS

8-1. INTRODUCTION.

8-2. The TMA 3000 Tape Motion Analyzer provides as options two types of remote controlled operations via two-way cable transmissions between host computer controllers and one or more TMA 3000 units. These two types of optional remote control interfaces are conventionally denoted:

a. RS-232C Interface Assembly, P/N 552115 (single unit configuration).

b. IEEE 488 Interface Assembly, P/N 552114 (party-line configuration).

8-3. The use of either of these remote control systems requires that the TMA 3000 be fitted with compatible printed-circuit board assemblies mounted at the rear panel of the TMA 3000; these optional interface assemblies are electrically connected to connector J2 of the Microprocessor board and provide the interface connector for the remote control cable. When either remote option is installed, it is enabled by activating the TMA 3000 front panel REM (remote) control.

8-4. The RS-232C Interface is better suited to remote applications where only one TMA 3000 instrument is connected to each RS-232C interface at a remote controller or where long distances (i.e., in excess of 50 feet) separate the controller and TMA 3000 instruments.

8-5. The IEEE 488 Interface provides the ability to connect up to 31 instruments to a common controller, implementing transfer of commands and data among the bus addresses. Using the IEEE 488 bus, a complete control, data gathering, and analysis system may be set up and configured to the particular needs of the installation.

8-6. Generally, programming of the TMA 3000 is similar for application of either interface, which vary only in minor differences between bus operation in each case.

8-7. RS-232C OPERATING CHARACTERISTICS.

8-8. The RS-232C interface uses an Intel 8251A serial communications circuit which is programmed for seven data bits, one stop bit, and odd transmit parity. Receive data is not checked for parity. The computer or terminal interfaced to the TMA 3000 must be configured for the same number of stop and data bits to ensure compatibility.

8-9. In the terminology of the RS-232C, the TMA 3000 is configured as Data Terminal Equipment (DTE), and must interface with a computer or terminal configured as Data Communications Equipment (DCE). Since these concepts are frequently confused, the pertinent interface lines are summarized below:

TMA 3000 Title	J1 Pin	Source	Comments
Receive Data (RxD)	2	Computer	Data to TMA 3000
Transmit Data (TxD)	3	TMA	Data to computer
Clear to Send (CTS)	4	Computer	Set TRUE by computer to enable TMA 3000 to transmit data. If CTS goes false, TMA 3000 will hold until it returns true.
Request to Send (RTS)	5	TMA	Set TRUE by TMA 3000 to indicate to computer that TMA 3000 has a message to send.
Data Terminal Ready (DTR)	6	TMA	Indicates to computer that TMA 3000 is ready to accept data.
Carrier Detect (CD)	8	TMA	Permanent TRUE - may be used to sense that TMA 3000 is active.
Data Set Ready (DSR)	20	Computer	Not used by TMA 3000.
Chassis Ground	1	--	Connected together in TMA 3000
Signal Ground	7	--	

8-10. Frequently, RS-232C interfaces are implemented with as few lines as RxD, TxD and ground. It is essential that DTR be included in the TMA 3000 interface and that the computer be programmed to observe protocol with respect to this line. The CTS input to the TMA 3000 may be left open, in which case the TMA 3000 will assume that the computer is always ready to receive data.

8-11. Because of the confusion that often exists around the RS-232C (RS stands for Recommended Standard), the user is advised to check that the computer is configured to source data on line 2, receive it on line 3, and read status on line 6 (DTR). If this is not the case, it may be possible to reverse the connections between lines 2 and 3 and 6 and 20 (at one end of the cable only) to effect a transformation from DTE to DCE.

8-12. TMA COMMAND PROTOCOL.

8-13. Each command sent to a TMA 3000 consists of a string of ASCII characters that describe the required operation. Such commands can range from three characters to as many as 10 and may be strung together in a single sequence of up to 32 characters that are terminated by carriage return, line feed sequence (i.e., CRLF sequence, ASCII hexadecimal ØD, ØA, which counts as two characters). The individual commands in a sequence should be separated by spaces or commas.

8-14. Once the TMA 3000 has received command line termination, each command in the sequence is interpreted and executed in succession. Upon completion of execution of all commands in the sequence, the TMA 3000 issues a null string (ASCII CRLF) as acknowledgment. If an incorrectly formed command is received, the command will not be executed, the TMA 3000 will cease processing the command line, and an error message will be issued. Query commands, where the TMA 3000 must respond with a data message, will result in either the data message or an error message.

8-15. The remote controller must be programmed to receive an ASCII message of up to 40 characters in length following every command sequence. It is imperative that this message be received before another command is issued; failure to observe this requirement will result in a hangup (i.e., a malfunction, which results in a lockup in an illegal mode) in the TMA 3000, the controller, the data bus, or in all three areas. For similar reasons, only one query command may be present in each sequence, and that query must be the last command in the sequence. Generation of only one query in any command sequence ensures that only a single message or acknowledgment will be issued by the TMA 3000 in response to each command sequence.

8-16. Execution time periods for the various commands range from less than 160 milliseconds for most simple commands to about 3 seconds for the DIAG command. It is recommended that the response timeouts for inputs to the TMA 3000 be set for 1 second for normal commands and for 5 seconds for query commands. These timeout periods will provide sufficient time for the TMA 3000 to respond without hanging up the controller in a malfunction.

8-17. TMA COMMANDS.

8-18. The commands that are recognizable by the TMA 3000 are divided into three categories:

- o Commands that duplicate TMA 3000 front-panel control functions.
- o Commands that set values.
- o Commands that query the TMA 3000 for a data response.

8-19. FRONT-PANEL FUNCTION COMMANDS. Commands that duplicate front-panel control functions are listed in table 8-1, Function Select Commands.

COMMAND	FUNCTION
TRACK	Selects frequency-tracking mode
@LPF	Selects auto low-pass filter mode
@METER	Selects auto-meter ranging
CAL/ON	Selects CAL mode - retains current FLUTTER/TBE setting
CAL/OFF	Deselects CAL mode
FLUTTER	Selects FLUTTER mode
TBE/SK	Selects TBE/Skew mode
SERVO	Selects Servo mode
1SIG 2SIG 3SIG	Selects statistical voltmeter SIGMA level
INPUT	Selects INPUT, deselects ANA
ANA	Selects ANA, deselects INPUT
FRONT	Selects FRONT panel data inputs
BACK	Selects BACK panel data inputs
VMR	Performs voltmeter reset to speed up meter settling

Table 8-1. TMA 3000 Function Select Commands

8-20. SET VALUE COMMANDS. Since any remote computer is able to generate digital binary values directly, it is able to set reference frequency, filter band width, meter range, analyzer center frequency and range specifically without utilizing up and down arrow functions. Value commands are distinguished by an equal (=) sign (e.g., "RFREQ=400" or "METER=3.0"). Value commands are listed in table 8-2. There should not be spaces between characters in a command. Spaces or commas are used to separate the various commands when a series of commands is transmitted in a single line.

COMMAND	FUNCTION
RFREQ=400 200 100 50 25 12 6.2 3.1 1.5	These commands set reference frequency. Three-digit match is required, except for 50, 25, 12, where leading space is optional. Trailing characters (e.g., "RFREQ=200 KHz" or "RFREQ=200000") are ignored; TMA 3000 executes command, but issues command error message.
FILTER=20 10 5 2.5 1.2 .62 .31 .15	These commands set low-pass filter bandwidth. Comments above apply regarding 3-digit match.
RANGE=20K 2K 200 20 2	These commands set analyzer frequency range. It is not necessary that ANA be selected to set RANGE. Three-digit match comments apply.
CFREQ=XXX	Where XXX represents one- to three-digit integer between Ø and 255 that is sent to analyzer DAC (digital-to-analog converter) to set analyzer center frequency. (Refer to section on calculated parameters for determination of XXX.)
METER=300 100 30 10 3.0 1.0 0.3	These commands set meter range, cancelling auto range if applicable. Specifying incorrect range will cause TMA 3000 to issue an error message and to ignore command. Exactly three digits must be specified, including decimal points and leading zeros. Because of similarity in range numbers, use of precise syntax is essential.

Table 8-2. Value Commands

8-21. QUERY COMMANDS. Five query commands cause the TMA 3000 to send a report to the remote controller. It is these commands that permit remote tabulation of data via the bus interface. Query commands are listed in table 8-3.

COMMAND	FUNCTION
STAT	TMA 3000 returns machine status. Status is represented in form of ASCII - encoded hexadecimal bytes that contain the complete machine state. See section entitled Status Decoding.
VERS	TMA 3000 returns message: TMA-3000 V#.#X ROM(C) YYMM where V#.#X refers to version (e.g., VI.ØD), ROM(C) is copyright message, and YYMM is version of year - month date (e.g., 8302 if February 1983). Version data is useful in troubleshooting and problem identification.
DATA	TMA 3000 returns next readings of frequency meter and analog meter: FREQ=ØØ25,Ø7KHz ADC=2Ø5 where frequency meter reading is directly in kilohertz and ADC reading is decimal equivalent of A/D converter output. Full scale on analog meter yields: ADC=204. Refer to section entitled Meter Decoding.
DIAG	TMA 3000 performs measurement of its power supplies and returns message: -12V=AAA -6V=BBB 12V=CCC 6V=DDD 5V=EEE where AAA - EEE are three-digit decimal equivalents of power supply values. All power supplies are attenuated to yield readings of 126-129 nominal. Readings below 116 or above 141 indicate that power supplies are out of tolerance.
CONTROL C	Upon receipt of control C (Hex Ø3, CHR$(3) in Basic notation), TMA 3000 will transmit "OK" to verify that two-way communication has been established between remote controller and TMA 3000.

Table 8-3. Query Commands

8-22. SELECTING RS-232C BAUD RATE.

8-23. When the optional RS-232C Interface is installed, the serial interface data rate, denoted as Baud rate, may be set by the operator to match most standard rates currently in use.

8-24. A four-position DIP switch is located on the RS-232C interface board and is accessible from the rear panel (just above the RS-232C connector). Table 8-4 lists the switch settings for each Baud rate. As a convenient reference, the corresponding clock frequency measured at test point TP1 of the interface board is also listed.

BAUD RATE	SWI-1	SWI-2	SWI-3	SWI-4	TP1 (kHz)
300	O	C	O	C	4.8
1200	O	O	O	C	19.2
2400	C	O	C	O	38.4
4800	C	C	O	O	76.8
9600	C	O	O	O	153.6

NOTE: O = open switch; C = closed switch.

Table 8-4. RS-232C Baud-Rate Selections

8-25. SELECTING IEEE 488 ADDRESS.

NOTE

The TMA 3000 is internally programmed to recognize the secondary address of Ø only. This secondary address MUST be used in all IEEE 488 communications.

8-26. Every device connected to an IEEE 488 bus must have a unique address. Accordingly, each TMA 3000 used in a test setup must have its own address selected by the user to match the address that the controller will use to command its operation. The TMA address is set by selecting the appropriate binary code on the 8-bit

DIP switch located above the IEEE 488 connector at the rear panel of the TMA 3000. Switches No. 1 (LSB) through 5 (MSB) may be set to any primary address from Ø (all switches open) to 31 (all switches closed). (Address Ø should be avoided as Ø is conventionally reserved for the bus controller.) If the TMA 3000 is operated with a controller, set switch No. 8 to closed (controller on line), and both switch 7 (TALK) and switch 6 (LISTEN) to open.

8-27. If no controller is on line, set switch No. 8 to open, switch No. 7 to open (TALK), and switch No. 6 (LISTEN) to closed. [In this mode (NO CONTROLLER ON LINE) these switch settings cause the TMA 3000 to execute any commands on the bus, but will disable data outputs and error messages.] In this mode, switches No. 6 and No. 7 are ENABLE switches (in the CONTROLLER ON LINE mode, these function as DISABLE switches).

8-28. Switches Ø through 5 specify the primary address (Ø through 31). An illustration of the address DIP switch settings, for example, address 7, Ø (primary address 7, secondary address is fixed at Ø) in a system with a controller where both talker and listener modes are enabled, is shown in figure 8-1.

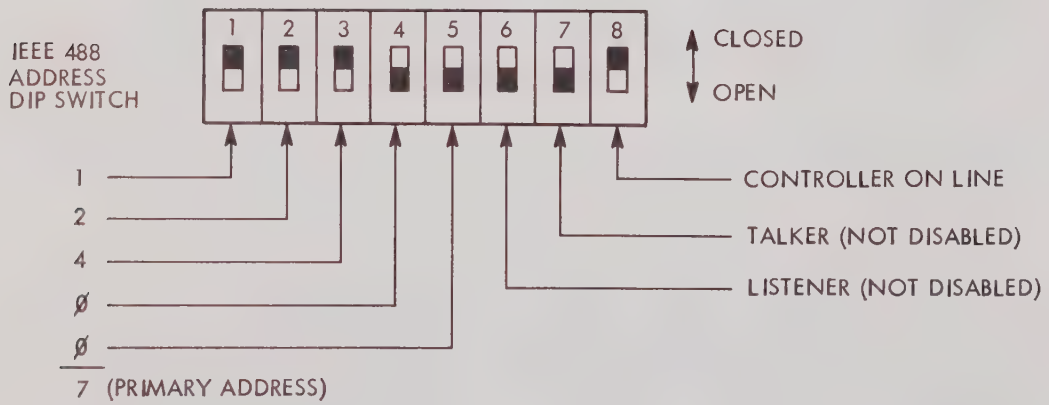


Figure 8-1. IEEE Addressing Example

8-29. SPECIAL IEEE 488 FUNCTIONS.

8-30. The TMA 3000 is configured only for general communications; the TMA 3000 does not generate service requests (SRQ) nor does it respond to group trigger (GET). The parallel polling protocol is not implemented in the TMA 3000.

8-31. The DEVICE CLEAR bus command generates a full reset of the TMA 3000.

CAUTION

The TMA reset returns the TMA 3000 to its power-on state and clears the REMote status; the remote operation is then disabled and can only be restored by the operator manually pressing the REM pushbutton on the TMA front panel.

8-32. TMA STATUS DECODING.

8-33. In response to a STAT command, the TMA will return a string of four ASCII encoded hexadecimal bytes which represent the present status of the instrument. The machine status must be referred to in order to interpret the data which is returned in response to a DATA command. Hexadecimal is used to minimize the length of the data string and because it is easily converted from and to the binary used within the microprocessor.

8-34. Each of the status bytes contains from two to eight fields, each dedicated to some specific characteristic of operation. For example, BYTE 0 is composed of two fields, the first of which indicates the low pass filter bandwidth and the second the reference frequency. A typical BYTE 0 might be 87, representing a low pass filter setting of 20 KHz and a reference frequency of 100 KHz. BYTE 1 comprises eight individual bits indicating whether the automatic modes (Meter, Filter, Track), Cal, or Remote are on or off; whether the frequency indication is in Hz or KHz; which inputs are selected (Front or Rear); and whether the meter data is to be interpreted as time (Microseconds) or percent (Flutter).

8-35. Table 8-5 gives the information necessary to decode the full status return. Recall that the ADC data returned as part of the response to a DATA command is a fraction of full scale (205 is full scale). The actual data reading is obtained by dividing the ADC data by 205 and multiplying by the meter range.

8-36. A typical status response might be:

78EFE404 <CRLF>

signifying:

78 10 KHz Filter Bandwidth, 200 KHz Reference Frequency

E Auto Meter On
Auto Filter On
Track On
Cal Off

F Remote On
KHz
Front Inputs
Meter reads Microseconds

E Frequency meter reads the Input frequency
Time Base Error
2 Sigma

4 1.0 (Microsecond) Full Scale

0 These bits not used

4 XXX.XX Frequency Meter Display (eg, 200.00)
Frequency Display not on hold

8-37. COMMUNICATION PROGRAMS FOR TMA 3000.

8-38. The programs in tables 8-6 and 8-7 provide for communication between the Commodore PET or Hewlett-Packard HP-87 computer and the TMA 3000. It is essential that the TMA 3000 be able to respond instantly to some commands from the computer or take considerably longer to respond to DATA and DIAG queries. DATA queries have to wait for the next data update. DIAG queries have to wait for a measurement sequence which may take several seconds. The TMA 3000 is rather inflexible in that it will hang up if there is not sufficient time to send its response.

8-39. TMA 3000 ADDRESSING. The TMA 3000 address switches should be set in accordance with paragraph 8-25 and figure 8-1.

8-40. TMA 3000 CLEARING. As stated previously, the TMA 3000 may hang up and generate an error message if not allowed to respond to queries. Clear a hang up by pressing the REMote switch to go out of the remote mode. Press REMote once more to return to the remote mode.

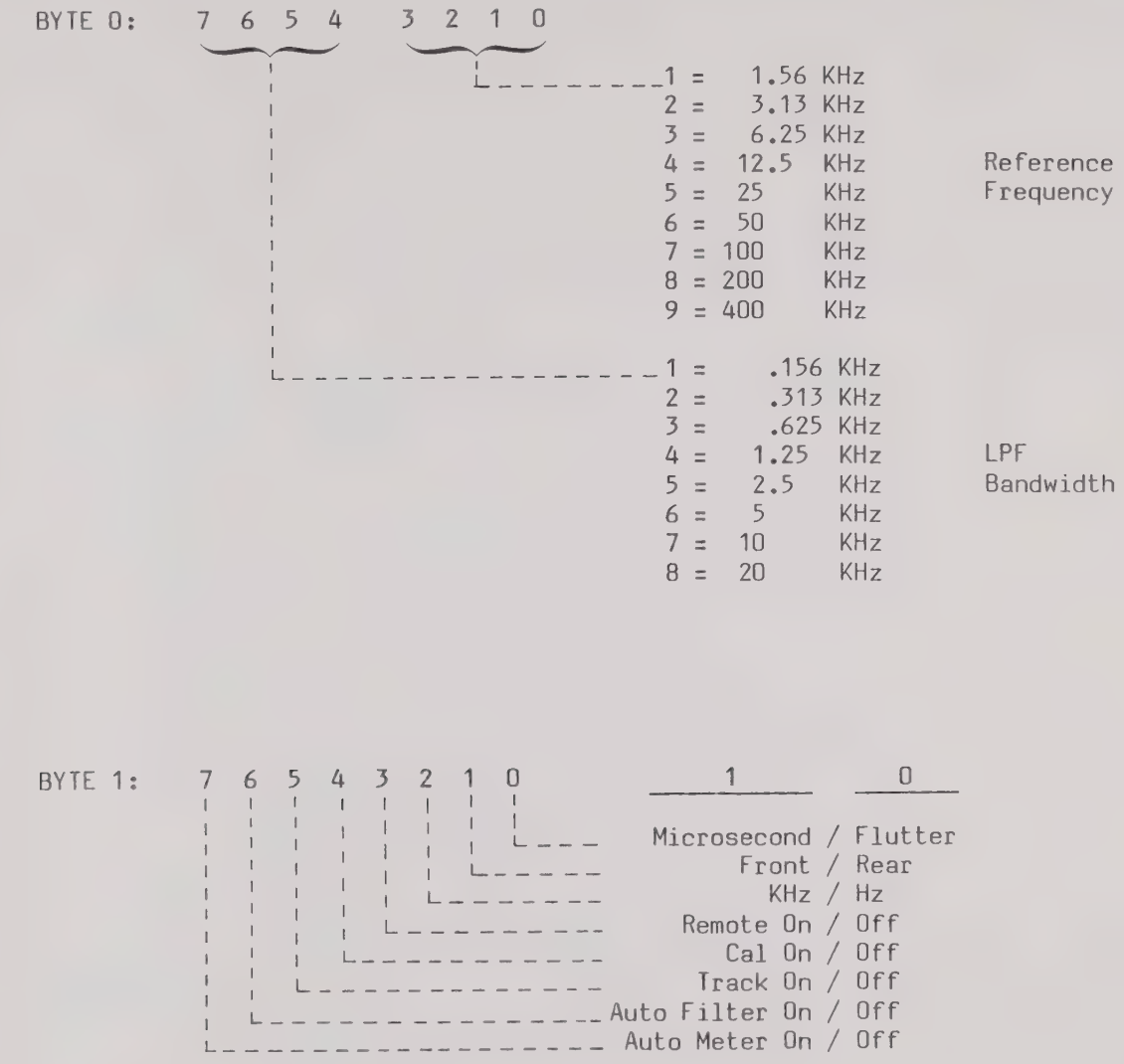


Table 8-5. Status Decoding (Sheet 1 of 2)

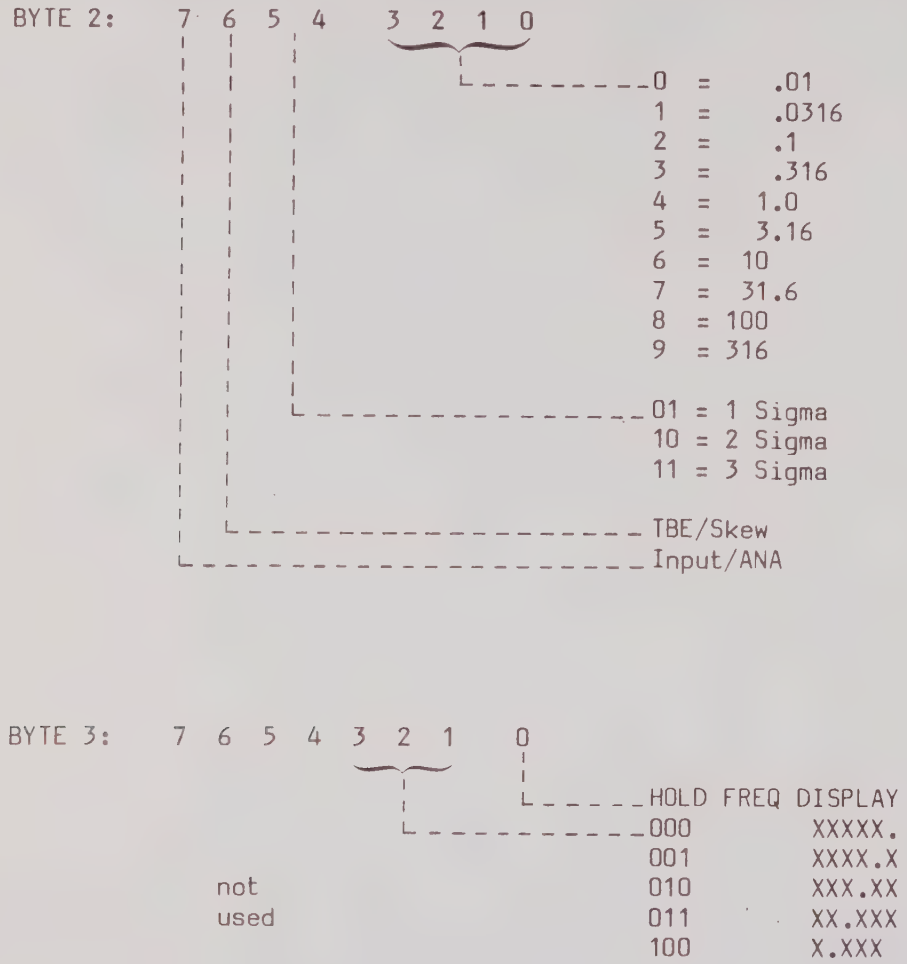


Table 8-5. Status Decoding (Sheet 2 of 2)

```
10 REM Interactive communications program for Commodore PET to
15 REM be used as tester for TMA-3000
20 OPEN 5,7,0 REM Open as device 7, secondary address 0 (TMA always uses
21 REM secondary address 0)
100 INPUT "MESSAGE" ; M$ REM Message to be sent to TMA
105 IF M$= "D" THEN 120 REM Use D to indicate that data will be returned
106 REM A longer time-out will be implemented for statements that request data
110 GOSUB 300
115 GOTO 100 REM Loop back after completing communication
120 INPUT "DATA MESSAGE" ; M$
130 GOSUB 400
140 GOTO 100
300 PRINT#5, M$
310 For I=0 TO 10 REM Uses PETs internal IEEE488 timeout (~64 mSec * 10)
320 INPUT#5, A$
325 IF ST=2 THEN NEXT I
330 IF A$="" THEN RETURN REM Null string signifies acceptance of cmd
340 PRINT A$
345 A$="" REM Resets A$ to null string
350 RETURN
400 PRINT#5, M$
405 FOR I=1 TO 1000 REM 64 mSEC * 1000 (DIAG command can take several seconds)
410 INPUT#5, A$
415 IF ST=2 THEN NEXT I
420 IF A$="" THEN RETURN
430 PRINT A$
435 A$=""
440 RETURN
```

Table 8-6. Commodore PET Communication Program

```
10 REM Interactive communications program for Hewlett-Packard HP-87
20 REM computer to be used as tester for TMA-3000
30 DIM A$[100]
40 RESET 7 !Reset interface
50 CLEAR ! Clears CRT
60 DISP "SYSTEM HAS RESTARTED"
70 ON TIMEOUT 7 GOTO 40 ! Restart program if interface times out
80 SET TIMEOUT 7;10,000 ! Timeout= 10 Secs
90 DISP "MESSAGE"; @ INPUT M$ ! Read the message to be sent to the TMA
100 SEND 7; CMD "U?'" SCG 0 DATA M$ EOL ! Send the message
110 WAIT 500 ! Allow .5 Secs for
120 SEND 7; UNL MLA TALK 7 SCG 0 ! Listen for the response
130 ENTER 7; A$ ! Get the response from the interface
140 IF A$="" THEN GOTO 160 ! Check response
150 DISP "INTERFACE SAYS"; A$ ! Display the response
160 A$="" ! Clear A$ before sending another message
170 GOTO 90 ! Loop around again
180 STOP
190 END
```

Table 8-7. Hewlett-Packard HP-87 Communication Program

MP MASTER
MA23461